I.C. ELECTRICIAN 1 & C

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSE NAVPERS 10557-A

PREFACE

This book is written for men of the United States Navy and Naval Reserve who are interested in qualifying for advancement to I.C. Electrician 1 or Chief I.C. Electrician. Combined with the necessary practical experience, this training course will help prepare the reader for the advancement-in-rating examination.

The qualifications for I.C. Electricians are listed in appendix II. These are current through change 19. Because examinations for advancement are based on these qualifications, interested personnel should refer to them frequently for guidance. Be sure you refer to an up-to-date set of qualifications; these change from time to time.

I.C. Electrician 1 and Chief was prepared by the U.S. Navy Training Publications Center, Washington, D.C., which is a field activity of the Bureau of Naval Personnel. Technical assistance was provided by the staff of the U.S. Naval School, I.C. Electricians, Class B, Great Lakes, Ill., and by other Navy activities cognizant of I.C. equipment and the duties of I.C. Electricians.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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READING LIST

NAVY TRAINING COURSES

I.C. Electrician 3, NavPers 10555-A

I.C. Electrician 2, NavPers 10556-A

I.C. Electrician 1 & C, NavPers 10557-A

Basic Hand Tool Skills (Metal Working Skills Only) NavPers 10058-A

Basic Electricity, NavPers 10086-A

Basic Electronics (Chapters 1 through 10, and chapter 17, only), NavPers 10087-A

OTHER PUBLICATIONS

Bureau of Ships Technical Manual, chapters 4; 6; 45, sections 1, 2, 3; 65; 88, sec III.

U. S. Navy Safety Precautions (chapter 19) OPNav 34P1

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your information and Education Officer.* The following is a partial list of those courses applicable to your rate:

Number	Title
C290	Physics I (Mechanics)
B858	The Slide Rule

*"Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified on the active duty orders."

CHAPTER 1

ADVANCEMENT

This course is written to aid the IC2 or IC1 in preparing for advancement to IC1 or Chief IC, respectively. There are many requirements for advancement in rating and they will be discussed later in this chapter. This training course deals primarily with the professional requirements or qualifications for IC1 and Chief as listed in change number 19 of the Manual of Qualifications for Advancement in Rating, (NavPers 18068). Any changes in qualifications occurring after change No. 19 are not reflected in the information given in this course.

Military requirements are discussed in the current edition of Basic Military Requirements (NavPers 10054), Military Requirements for Petty Officers 3 & 2 (NavPers 10056), and Military Requirements for Petty Officers 1 & C (NavPers 10057).

Chapter 2 of this training course presents information concerning the electrical division organization and administration. Suggestions regarding planning, organizing, assigning, and supervising work for both the IC and EM groups are presented. In addition, division training is discussed.

Chapter 3 discusses engineering records and reports with emphasis being placed on those that apply to the IC group.

Chapters 4, 5, 6, and 7 concern magnetic amplifier applications, gyrocompass systems, and dead reckoning equipment.

Chapter 8 concerns closed circuit TV equipment, and chapter 9 discusses safety precautions with emphasis being placed on electrical safety precautions.

The remainder of this chapter contains information that will help you in preparing for advancement. It is strongly recommended that you study this chapter carefully before beginning intensive study of the remainder of this training course.

THE ENLISTED RATING STRUCTURE

The present enlisted rating structure, established in 1957, includes three types of ratings—general ratings, service ratings, and emergency ratings.

GENERAL RATINGS are designed to provide paths of advancement and career development. A general rating identifies a broad occupational field of related duties and functions requiring similar aptitudes and qualifications. General ratings provide the primary means used to identify billet requirements and personnel qualifications. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

Subdivision of certain general ratings are identified as SERVICE RATINGS. These ratings identify specific areas of specialization within the scope of a general rating. Service ratings are established in those general ratings in which specialization is essential for efficient utilization of personnel. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

EMERGENCY RATINGS identify essentially civilian occupational fields. Emergency ratings do not need to be identified as ratings in the peacetime Navy, but their identification is required in time of war.

THE I.C. RATING

The I. C. rating was established in 1948, and is a general rating only. I. C. electricians maintain and repair interior communications (IC) systems, gyrocompass systems, dead reckoning

systems, amplified and unamplified voice systems, alarm and warning systems, and related equipment. These systems and equipment are continually being modified and improved and new equipment is continually being developed. This requires constant study for the I. C. man in order to keep abreast of the changes.

I. C. rates are included in the personnel allowance for practically all types of Navy ships, including tenders and repair ships. ICC billets, however, are normally restricted to the larger ships. Shore duty billets for First Class and Chief Interior Communications Electricians include recruiting duty and instructor duty at class "A" and "B" schools, Naval Reserve Training Center, Naval Examining Centers, and Naval Training Publications Center. As an IC2 you are already aware of the importance of your job in maintaining the I. C. equipment, and realize the fact that this equipment must function properly if the ship is to carry out her mission effectively. As you prepare for further advancement you must broaden your thinking along these lines and realize that the equipment assigned to all other divisions of the ship must also function properly if the ship is to accomplish her mission.

In the past your primary concern has most likely been restricted to the maintenance and upkeep of the I. C. circuits assigned to you, and you have directed your own efforts and those of the men under you to this end. As the leading I. C. electrician you must learn to cooperate with, and secure the cooperation of, other divisions in accomplishing the department's or ship's mission. This is true for all leading petty officers, of course, but it is especially true for the leading I. C. electrician, as much of the I. C. equipment is so closely related to, and associated with, equipment assigned to other divisions. On many ships, I. C. electricians share the same watch stations and work shops with men from other divisions. This arrangement has given rise to many inter-division problems in the past, and will continue to do so in the future. Most of these are the problems of the leading petty officer and should be handled at this level.

Thus as the leading I. C. electrician you are going to be vitally concerned with carrying out the ship's mission, and the Navy's mission, through people—which is naval leadership.

As a result of the naval leadership program a considerable amount of material related to naval leadership for the senior petty officer is available to you. Studying this material will make you aware of your many leadership responsibilities as a senior petty officer and will also be of great help to you in developing your leadership qualifies. It will not, however, in itself, make you a good leader. Leadership principles can be taught, but a good leader acquires that quality only through hard work and practice.

As you study this material containing leadership traits, keep in mind that probably none of our most successful leaders possessed all of these traits to a maximum degree, but a weakness in some traits was more than compensated for by strength in others. Critical self-evaluation will enable you to realize the traits in which you are strong, and to capitalize on them. At the same time you must constantly strive to improve on the traits in which you are weak.

Your success as a leader will be decided for the most part by the success with which you have inspired others to learn and perform, due to your own personal example.

ADVANCEMENT IN RATING

By this time, you are aware of the personal advantages of advancement in rating—higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your chosen career. You have also discovered that one of the most enduring rewards of advancement is the training you acquire in the process of preparing for advancement.

The Navy also profits by your advancement. Highly trained personnel are essential to the functioning of the Navy. With each advancement in rating, you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating. And second (and equally important), you become more valuable as a person who can supervise, lead, and train others and thus make far-reaching contributions to the entire Navy.

Since you are studying for advancement to PO1 or CPO, you are probably familiar with the requirements and procedures for advancing in rating. However, you will find it helpful to read the following sections of this chapter. It is possible that some of the requirements have changed since the last time you were going up for advancement in rating. Furthermore, you will be responsible for training others for advancement, and so will need to know the requirements in some detail.

HOW TO QUALIFY FOR ADVANCEMENT

To qualify for advancement in rating, a person must:

1. Have a certain amount of time in grade.
2. Complete the required military and professional training courses.
3. Demonstrate the ability to perform all the PRACTICAL requirements for advancement by completing the Record of Practical Factors, NavPers 760.
4. Be recommended by his commanding officer.
5. Demonstrate his KNOWLEDGE by passing a written examination on (a) military requirements, and (b) professional qualifications.

Some of these general requirements may be modified in certain ways. Figure 1-1 gives an overall view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

Remember that the requirements for advancement can change. Check with your information and education officer to be sure that you know the most recent requirements.

When you are training lower rated personnel, it is a good idea to point out that advancement in rating is not automatic. Meeting all the requirements makes a person ELIGIBLE for advancement, but does not guarantee his advancement. Such factors as the score made on the written examination, length of time in service, performance marks, and the quotas for the rating enter into the final determination of who will actually be advanced.

HOW TO PREPARE FOR ADVANCEMENT

Preparations for advancement in rating include studying the qualifications, working on the practical factors, studying the required Navy Training Courses, and studying any other material that may be specified for the rate and rating. To prepare for advancement yourself or to help others prepare for advancement, you will need to be familiar with (1) the Quals Manual, (2) the Record of Practical Factors, NavPers 760, (3) a NavPers publication called Training Publications for Advancement in Rating, NavPers 10052, and (4) Navy Training Courses. The following sections describe these materials and give some information on how to use them to best advantage.

The Quals Manual

The Manual of Qualifications for Advancement in Rating, NavPers 18068 (with changes), gives the minimum requirements for advancement to each rate within each rating. This manual is usually called the "Quals Manual," and the qualifications themselves are often called "equals." The qualifications are of two general types: (1) military requirements, and (2) professional or technical qualifications. Military requirements apply to all ratings rather than to any one rating alone. Professional qualifications are technical or professional requirements that are directly related to the work of each rating.

Both the military requirements and the professional qualifications are divided into subject matter groups. Then, within each subject matter group, they are divided into PRACTICAL FACTORS and KNOWLEDGE FACTORS.

The professional qualifications for advancement in your rating are printed as an appendix at the back of this training course. These qualifications were current at the time this training course was printed. However, the Quals Manual is changed more frequently than Navy Training Courses are revised. By the time you are studying this training course, therefore, the quals for your rating may have been changed. Always check the change number against any up to date copy of the Quals Manual to be sure you are studying the proper material.

In training others for advancement in rating, emphasize these three points about the quals:

1. The quals are the MINIMUM requirements for advancement to each rate within the rating. Personnel who study MORE than the required minimum will have a great advantage when they take the written examinations for advancement.

2. Each qual has a designated rate level—chief, first class, second class, or third class. You are responsible for meeting all quals specified for the rate level to which you are seeking advancement AND all quals specified for lower rate levels. To advance to chief, therefore, you must meet all requirements for advancement to all rates within the rating.

3. The written examinations for advancement in rating will contain questions relating to the practical factors AND to the knowledge factors of BOTH the military requirements and the professional qualifications.

ACTIVE DUTY ADVANCEMENT REQUIREMENTS

<table>
<tr><th>REQUIREMENTS *</th><th>E1 to E2</th><th>E2 to E3</th><th>E3 to E4</th><th>E4 to E5</th><th>E5 to E6</th><th>E6 to E7</th><th>† E7 to E8</th><th>‡ E8 to E9</th></tr>
<tr><td>SERVICE</td><td>4 mos. service—or completion of recruit training.</td><td>6 mos. as E-2.</td><td>6 mos. as E-3.</td><td>12 mos. as E-4.</td><td>24 mos. as E-5.</td><td>36 mos. as E-6.</td><td>48 mos. as E-7. 8 of 11 years total service must be enlisted.</td><td>24 mos. as E-8. 10 of 13 years total service must be enlisted.</td></tr>
<tr><td>SCHOOL</td><td>Recruit Training.</td><td></td><td>Class A for PR3, DT3, PT3. ǂAME 3</td><td></td><td></td><td>Class B for AGCA, MUCA, MNCA.</td><td>Must be permanent appointment.</td><td></td></tr>
<tr><td>PRACTICAL FACTORS</td><td>Locally prepared check-offs.</td><td colspan="7">Records of Practical Factors, NavPers 760, must be completed for E-3 and all PO advancements.</td></tr>
<tr><td>PERFORMANCE TEST</td><td colspan="2"></td><td colspan="4">Specified ratings must complete applicable performance tests before taking examinations.</td><td></td><td></td></tr>
<tr><td>ENLISTED PERFORMANCE EVALUATION</td><td colspan="2">As used by CO when approving advancement.</td><td colspan="6">Counts toward performance factor credit in advancement multiple.</td></tr>
<tr><td>EXAMINATIONS</td><td colspan="2">Locally prepared tests.</td><td colspan="4">Service-wide examinations required for all PO advancements.</td><td colspan="2">Service-wide, selection board, and physical.</td></tr>
<tr><td>NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)</td><td></td><td colspan="5">Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).</td><td colspan="2">Correspondence courses and recommended reading. See NavPers 10052 (current edition).</td></tr>
<tr><td rowspan="2">AUTHORIZATION</td><td colspan="2">Commanding Officer</td><td colspan="3">U.S. Naval Examining Center</td><td colspan="3">Bureau of Naval Personnel</td></tr>
<tr><td colspan="6">TARS are advanced to fill vacancies and must be approved by CNARESTRA.</td><td colspan="2"></td></tr>
</table>

* All advancements require commanding officer's recommendation.
† 2 years obligated service required.
‡ 3 years obligated service required.
ǂ Effective 1 Jan. 1963.

5.1

Figure 1-1.—Active duty advancement requirements.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS *		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
	FOR THESE DRILLS PER YEAR								
TOTAL TIME IN GRADE	48	6 mos.	6 mos.	15 mos.	18 mos.	24 mos.	36 mos.	48 mos.	24 mos.
	24	9 mos.	9 mos.	15 mos.	18 mos.	24 mos.	36 mos.	48 mos.	24 mos.
	NON-DRILLING	12 mos.	24 mos.	24 mos.	36 mos.	48 mos.	48 mos.		
DRILLS ATTENDED IN GRADE †	48	18	18	45	54	72	108	144	72
	24	16	16	27	32	42	64	85	32
TOTAL TRAINING DUTY IN GRADE †	48	14 days	14 days	14 days	14 days	28 days	42 days	56 days	28 days
	24	14 days	14 days	14 days	14 days	28 days	42 days	56 days	28 days
	NON-DRILLING	None	None	14 days	14 days	28 days	28 days		
PERFORMANCE TESTS				Specified ratings must complete applicable performance tests before taking examination.					
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 760, must be completed for all advancements.							
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.							
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.						Standard EXAM, Selection Board, and Physical.	
AUTHORIZATION		District commandant or CNARESTRA					Bureau of Naval Personnel		

* Recommendation by commanding officer required for all advancements.
† Active duty periods may be substituted for drills and training duty.

5.2

Figure 1-2.—Inactive duty advancement requirements.

Record of Practical Factors

A special form known as the RECORD OF PRACTICAL FACTORS, NavPers 760, is used to record the satisfactory performance of the practical factors. This form, which is available for all ratings, lists all the military and professional practical factors. Whenever a person demonstrates his ability to perform a practical factor, appropriate entries must be made in the DATE and INITIALS columns. As a PO1 or CPO, you will often be required to check the practical factor performance of lower rated personnel and to report the results to your supervising officer.

As changes are made periodically to the Quals Manual, new forms of NavPers 760 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement. Keep this in mind when you are training or supervising other personnel. If a person demonstrates proficiency in some skill which is not listed in the quals but which is within the general scope of the rating, report this fact to the supervising officer so that an appropriate entry can be made in the Record of of Practical Factors.

When you are transferred, the Record of Practical Factors should be forwarded with your service record to your next duty station. It is a good idea to be sure that this form is actually inserted in your service record before you are transferred. If the form is not in your record, you may be required to start all over again and requalify in practical factors that have already been checked off. You should also take some responsibility for helping lower rated personnel keep track of their practical factor records.

NavPers 10052 (Revised)

Training Publications for Advancement in Rating, NavPers 10052 (revised), is a very important publication for anyone preparing for advancement in rating. This publication lists required and recommended Navy Training Courses and other reference material to be used by personnel working for advancement in rating. NavPers 10052 is revised and issued once each year by the Bureau of Naval Personnel. Each revised edition is identified by a letter following the NavPers number. When using this publication, be SURE that you have the most recent edition.

The required and recommended references are listed by rate level in NavPers 10052. It is important to remember that you are responsible for all references at lower rate levels, as well as those listed for the rate to which you are seeking advancement.

Navy Training Courses which are marked with an asterisk (*) in NavPers 10052 are MANDATORY at the indicated rate levels. A mandatory training course may be completed by (1) passing the appropriate Enlisted Correspondence Course that is based on the mandatory training course; (2) passing locally prepared tests based on the information given in the training course; or (3) in some cases, successfully completing an appropriate Navy school.

When training personnel for advancement in rating, do not overlook the section of NavPers 10052 which lists the required and recommended references relating to the military requirements for advancement. Personnel of all ratings must complete the mandatory military requirements training course for the appropriate rate level before they can be eligible to advance in rating. Also, make sure that personnel working for advancement study the references which are listed as recommended but not mandatory in NavPers 10052. It is important to remember that ALL references listed in NavPers 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Navy Training Courses

There are two general types of Navy Training Courses. RATING COURSES (such as this one) are prepared for most enlisted ratings. A rating training course gives information that is directly related to the professional qualifications of ONE rating. SUBJECT MATTER COURSES or BASIC COURSES give information that applies to more than one rating.

Navy Training Courses are revised from time to time to bring them up to date. The revision of a Navy Training Course is identified by a letter following the NavPers number. You can tell whether a Navy Training Course is the latest edition by checking the NavPers number (and the letter following the number) in the most recent edition of List of Training Manuals and Correspondence Courses, NavPers 10061.

Navy Training Courses are designed for the special purpose of helping naval personnel prepare for advancement in rating. By this time, you have probably developed your own way of studying these courses. Some of the personnel you train, however, may need guidance in the use of Navy Training Courses. Although there is no single "best" way to study a training course, the following suggestions have proved useful for many people.

1. Study the military requirements and the professional qualifications for your rating before you study the training course, and refer to the quals frequently as you study. Remember, you are studying the training course primarily to meet these quals.

2. Before you begin to study any part of the training course intensively, get acquainted with the entire book. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

3. Look at the training course in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the book.

4. When you have a general idea of what is in the training course and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit--it may be a chapter, a section of a chapter, or a subsection. The amount of material you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

5. In studying each unit, write down questions as they occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

6. As you study, relate the information in the training course to the knowledge you already have. When you read about a process, a skill, or a situation, ask yourself some questions. Does this information tie in with past experience? Or is this something new and different? How does this information relate to the qualifications for advancement in rating?

7. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Without looking at the training course, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

8. Use Enlisted Correspondence Courses whenever you can. The correspondence courses are based on Navy Training Courses or other appropriate texts. As mentioned before, completion of a mandatory Navy Training Course can be accomplished by passing an Enlisted Correspondence Course based on the training course. You will probably find it helpful to take other correspondence courses, as well as those based on mandatory training courses. Taking a correspondence course helps you to master the information given in the training course, and also gives you an idea of how much you have learned.

INCREASED RESPONSIBILITIES

When you assumed the duties of a PO3, you began to accept a certain amount of responsibility for the work of others. With each advancement in rating, you accept an increasing responsibility in military matters and in matters related to the professional work of your rating. When you advance to PO1 or CPO, you will find a noticeable increase in your responsibilities for leadership, supervision, training, working with others, and keeping up with new developments.

Leadership and Supervision

As a PO1 or CPO, both officers and enlisted personnel will regard you as a leader and supervisor. They will expect you to translate the general orders given by officers into detailed, practical, on-the-job language that can be understood and followed by relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their jobs correctly. At the same time, you must be able to explain to officers any important problems or needs of enlisted personnel. In all military and professional matters, your responsibilities will extend both upward and downward.

Along with your increased responsibilities, you will also have increased authority. Officers and petty officers have POSITIONAL authority—that is, their authority over others lies in their position. If your CO is relieved, for example, he

no longer has the degree of authority over you that he had while he was your CO, although he still retains the military authority that all seniors have over subordinates. As a PO1, you will sometimes have a certain degree of positional authority; as a CPO, you will have positional authority quite often. When exercising your authority, remember that it is positional—it's the rate you have, rather than the person you are, which gives you this authority. Orders are given for one purpose only—to help in accomplishing the mission of the organization.

Training

As a PO1 or CPO, you will have regular and continuing responsibilities for training others. Even if you are lucky enough to have a group of subordinates who are all highly skilled and well trained, you will still find that training is necessary. For example, you will always be responsible for training lower rated personnel for advancement in rating. Also, some of your best workers may be transferred, or personnel who are not so skillful or so well trained may be assigned to you. Or a particular job may call for skills that none of your personnel have. These and similar problems require that you be a training specialist—one who can conduct formal and informal training programs to qualify personnel for advancement in rating and who can train individuals and groups in the effective execution of assigned tasks.

In using this training course, study the information from two points of view. First, what do you yourself need to learn from it? And second, how would you go about teaching this information to others?

Training goes on all the time. Every time a person does a particular piece of work, some learning is taking place. As a supervisor and as a training expert, one of your biggest jobs is to see that your personnel learn the RIGHT things about each job and that they do not acquire bad work habits. An error that is repeated a few times is well on its way to becoming a habit. You will have to learn to walk a fine line between oversupervising and not supervising enough. No one can do his best work with a supervisor constantly supervising. On the other hand, you can't turn an entire job over to an inexperienced person and expect him to do it without any assistance or supervision.

In training lower rated personnel, emphasize the importance of learning and using correct terminology. A command of the technical language of your rating enables you to receive and convey information accurately and to exchange ideas with others. A person who does not understand the precise meaning of terms used in connection with his rating is definitely at a disadvantage when he tries to read official publications related to his rating. He is also at a great disadvantage when he takes the examinations for advancement in rating. In order to train others in the use of correct terminology, you will need to be very careful in your own use of words. Using correct terminology and insisting that your students use it will actually make it easier for the student to acquire information.

You will find the Record of Practical Factors, NavPers 760, a useful guide in planning and carrying out training programs. From this record, you can tell which practical factors have already been checked off and which ones have not yet been done. Use this knowledge to plan a training program that will fit the needs of the personnel you are training.

On-the-job training is usually controlled through daily and weekly work assignments. When you are working on a tight schedule, you will generally want to assign each person to the part of the job that you know he can do best. In the long run, however, you will gain more by assigning personnel to a variety of jobs so that they can acquire broad experience. By giving personnel a chance to do carefully supervised work in areas in which they are relatively inexperienced, you will increase the range of skills of each person and thus improve the flexibility of your working group.

Working With Others

As you advance to PO1 or CPO, you will find that many of your plans and decisions affect a large number of people. As the scope of your responsibility becomes greater, decisions that you make may have a direct effect on the work of personnel who are not even in your own rating. It becomes increasingly important, therefore, for you to understand the duties and responsibilities of personnel in other ratings. Every petty officer in the Navy is a technical specialist in his own field. Learn as much as you can about the work of other ratings, and plan your own work so that it will fit into the overall mission of the organization.

Keeping Up With New Developments

Practically everything in the Navy—policies, procedures, publications, equipment, systems—is subject to change and development. As a PO1 or CPO, you have a particular responsibility for keeping yourself informed about changes and new developments that affect you or your work in any way.

Some changes will be directly called to your attention, but others you will have to look for. Try to develop a special kind of alertness for new information. When you hear about anything new in the Navy, find out whether there is any way in which it might affect your work. If so, find out more about it.

SOURCES OF INFORMATION

As a PO1 or CPO, you must have an extensive knowledge of the references to consult for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the professional qualifications of your rating.

Some publications are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made.

A list of training courses and publications that will be helpful to you as references and for additional study in preparing for advancement is included in the reading list at the beginning of this text. Additional training courses applicable to the I. C. rating are available through your information and education officer.

In addition to training courses and publications, training film furnishes a valuable source of supplementary information. A selected list of training films that may be useful to you appears in Appendix I of this training course. Other films that may also be helpful are listed in the U. S. Navy Film Catalog NavPers 1000 (revised).

ADVANCEMENT OPPORTUNITIES FOR PETTY OFFICERS

Making chief is not the end of the line as far as advancement is concerned. Proficiency pay, advancement to E-8 and E-9, and advancement to commissioned officer status are among the opportunities that are available to qualified petty officers. These special paths of advancement are open to personnel who have demonstrated outstanding professional ability, the highest order of leadership and military responsibility, and unquestionable moral integrity.

PROFICIENCY PAY

The Career Compensation Act of 1949, as amended, provides for the award of proficiency pay to designated enlisted personnel who possess special proficiency in a military skill. Proficiency pay is given in addition to your regular pay and allowances and any special or incentive pay to which you are entitled. Enlisted personnel in pay grades E-4 through E-9 are eligible for proficiency pay. Proficiency pay is allocated by ratings, with most awards being given in the ratings which are designated as critical. The eligibility requirements for proficiency pay are subject to change. In general, however, you must be recommended by your commanding officer, have a certain length of time on continuous active duty, and get a sufficiently high mark on a Navywide proficiency examination in the subject matter of your own rating.

ADVANCEMENT TO E-8 AND E-9

Chief petty officers may qualify for the advanced grades E-8 and E-9 which are now provided in the enlisted pay structure. These advanced grades provide for substantial increases in pay, together with increased responsibilities and additional prestige. The requirements for advancement to E-8 and E-9 are subject to change, but in general include a certain length of time in grade, a certain length of time in the naval service, a recommendation by the commanding officer, and a sufficiently high mark on the servicewide examination. The final selection for E-8 and E-9 is made by a regularly convened selection board.

ADVANCEMENT TO COMMISSIONED OFFICER

The Limited Duty Officer (Temporary) Program provides a path of advancement to commissioned officer status for outstanding petty officers of the Regular Navy. LDOs are limited in their duty to the broad technical fields associated with their former rating.

Advancement to LDO may be made from

PO1 or above. Appointments are generally made to the grade of ensign; however, certain chief petty officers who have served at least 18 years and 6 months on active duty may apply for appointment to lieutenant (junior grade). Education, length of service, and maximum age limits are usually specified in the requirements for advancement to LDO. However, these requirements vary according to circumstances. If you are interested in advancing to LDO, ask your information and education officer for the latest requirements that apply to your particular case.

Another path of advancement to commissioned officer status is provided by the Integration Program. Enlisted personnel possessing the required qualifications may be appointed under this program to the grade of ensign in the Line, Supply, or Civil Engineer Corps of the Regular Navy. Education, length of service, and maximum age limits are included in the requirements for eligibility under this program. Eligibility requirements for this program, as well as for the other programs discussed here, are subject to change.

CHAPTER 2

ORGANIZATION AND ADMINISTRATION

Navy ships are operated under standard administrative and battle organizations as prescribed by Navy Regulations, to facilitate rapid expansion, without major changes, from peacetime to wartime status.

These organizations divide the ship's personnel into the following departments: Operations; Navigation; Gunnery or Deck; Engineering; Supply; and Medical and Dental. Aircraft carriers and seaplane tenders have, in addition, an air department, and repair ships have a repair department.

Ship organization and the organization of the various departments within the ship's organization, will vary slightly for different types of ships, but for a particular type and class of ship, they remain basically standard.

Division organization also remains basically standard. However, it is more flexible then ship or department organization, and may vary between ships of the same type and class. These variations are usually due to factors such as, differences in the number or experience of personnel assigned to the division, differences in ship employment or material conditions, and division officers or senior petty officers utilizing different methods in organizing and running their divisions.

This chapter will discuss electrical division organization and administration. Primary emphasis will be placed on the IC group. However, some information will be presented concerning the EM group.

ELECTRICAL DIVISION ORGANIZATION

The electrical (E) division organization must provide for the proper operation, maintenance, and repair of all electrical equipment under the cognizance of the electrical officer. In addition, the organizational framework must provide for training the division personnel, upkeep of the ship spaces assigned to the division, and manning electrical equipments and stations necessary under the various ship's readiness conditions.

All electrical equipment assigned to the E division may, for operating, maintenance, and repair purposes, be divided into three major types of equipments; Lighting, Power, and IC. Lighting and power equipments are assigned to the EM group and IC equipments (interior communications, ship control and navigation, alarm and warning systems and so forth) are assigned to the IC group as shown by figure 2-1. This division into three major types of equipments is applicable to, and is standard practice, on most Navy ships. Usually, no further subdivision of the electrical equipment is required for small ships. For large ships, however, the three major types of equipments must be divided further into subgroups. The size of the ship concerned and the number of personnel assigned to the division are the major factors in determining the number of these subgroups. The subgroups of electrical equipment shown in figure 2-1, are not for any one particular type of ship, but can be used as a guide for any type ship.

Any partition of the electrical equipment must include all of the equipment assigned to the division, and related equipment as far as practicable should be in the same subgroup.

IC GROUP

The I. C. Electricians in the electrical division are assigned to the IC group under the senior I. C. Electrician. On large ships the senior I. C. Electrician will usually be a Chief I. C. Electrician and subgroup supervisors IC1 or IC2. The remainder of the IC personnel are assigned to the different subgroups, and are under the direct supervision of the subgroup supervisors (fig. 2-1).

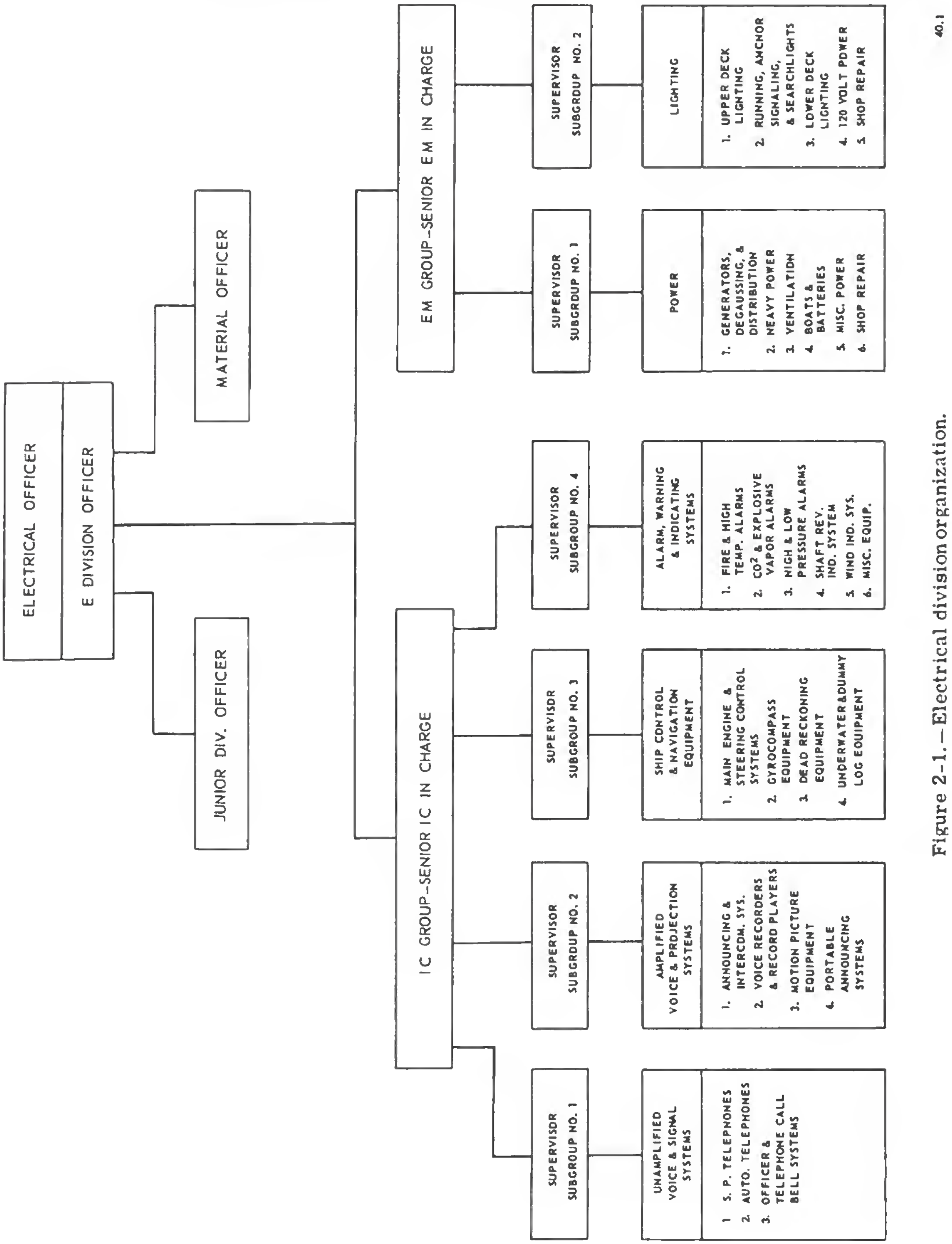


Figure 2-1.—Electrical division organization.

EM GROUP

The Electrician's Mates in the electrical division are assigned to the EM group under the senior Electrician's Mate. The senior Electrician's Mate will, in most cases, be a Chief Electrician's Mate, and large ships may have one or more Chief Electrician's Mates as power or lighting subgroup supervisors.

DUTIES AND RESPONSIBILITIES

The electrical officer is responsible, under the engineer officer, for the organization and administration of the electrical division, and its assigned personnel and material in support of the overall mission of the ship. He is further responsible for the operation, maintenance, and repair of the electrical machinery and systems throughout the ship, except those specifically assigned to another department.

The E division officer is responsible, under the electrical officer, for the organization, administration and operation of the E division. He is assisted by the senior division petty officer in carrying out such duties as:

1. Directing the operation of the division through the leading petty officers as prescribed by the division organization manual.
2. Assigning personnel to watches and duties within the divisions, and developing rotation programs for battle stations, watches, and general duties, to ensure the training and proficiency of the assigned personnel.
3. Scheduling training and initiating enlisted performance evaluation sheets for the division personnel.
4. Making recommendations for personnel transfers and changes in the division allowance to the electrical officer.
5. Ensuring that prescribed security measures are strictly observed by personnel of the division.
6. Conducting periodic inspection to evaluate performance and discipline of the division and initiating disciplinary action, when deemed necessary, in accordance with the Uniform Code of Military Justice and other regulatory directives.

The Junior Division Officer assists the division officer in coordinating and administering the division and acts as the division officer in the absence of the regularly assigned division officer.

The material officer is responsible under, and acts as technical assistant to, the electrical officer and division officer. He is responsible for the readiness of all assigned electrical equipment and the administration of the electrical Material Maintenance Program.

The senior I. C. Electrician acts as assistant to the material officer, and in performing his duties shall:

1. Direct and supervise, through the subgroup supervisors, the maintenance and repair of all IC equipment.
2. Instruct personnel in the proper methods of performing preventive maintenance.
3. Ensure that equipment history cards, field changes record cards, repair records cards, resistance tests cards, alteration record cards, and preventive maintenance checkoff cards are up to date.
4. Ensure that complete stocks of all maintenance repair parts are maintained and provide technical assistance to the supply department in maintaining a full allowance of on-board spare parts.
5. Be responsible to the material officer for all test equipment and accessories, and for their proper working condition.
6. Supervise the upkeep of all assigned IC spaces.
7. Supervise the preparation of the equipment inventory for the material officer.
8. Maintain the file of IC records and reports and ensure that they are up to date.

The senior Electrician's Mate, acting as assistant to the material officer, performs the same general duties for the EM group as those listed for the senior I. C. Electrician.

PLANNING, ORGANIZING, AND SUPERVISING WORK

Almost any activity runs more smoothly and successfully if there is some planning behind it. Work planning is the setting up, in advance, of jobs to be done, when they are to be done, how and where they are to be done, and who is to do them. The difference between good and poor work planning is the difference between order and confusion, between things being done on time and not being done on time and between pleasant working relationships and a work day full of conflicts. Good work planning is essential for best results even under ideal conditions and especially so when the activity is short handed.

As the leading I. C. Electrician you will be the key man in planning, organizing, and supervising the work for the IC group. You can suspect poor work planning as the cause if you are run ragged trying to keep up with the work load; if some of your men are doing all the work while others are idle; if there is quarreling, bickering, and confusion among the men; if work is held up for lack of materials; if jobs are not getting done on time; if equipment is frequently out of commission; and if it is necessary to work your men frequently after working hours or during holiday routine.

The major steps in managing a heavy work load are effective planning and organizing, and assigning and supervising the work.

PLANNING AND ORGANIZING WORK

Effective planning and organizing of the work require knowledge, foresight, judgment, and experience. In planning the work for the IC group, you will have to know the men in the group—their strong and weak points, the jobs they can do well, and the jobs they do poorly. You should know the IC equipment on your ship as well, or better, than any man in the group. You will have to know the amount of material, special tools and equipment and man-hours normally required for the various jobs. In addition you will have to know how to apportion big jobs into small operations.

You must have foresight. You will have to learn to anticipate difficulties and to either avoid them or be prepared for them when they arise. These requirements involve keeping yourself informed of the ship's operating schedule, and determining in advance how this schedule will affect the IC equipment and your work load; frequent checks with subgroup supervisors and inspections of all routine preventive maintenance checks and tests of the IC equipment, noting any results that may indicate future failure of the equipment; assuring yourself that necessary supplies, material, and repair parts are available on board or on order; and keeping in mind how your available manpower will be affected by future leaves, transfers, and discharges.

You will have to exercise judgment in your job priorities so that the most important jobs are accomplished first. Job priorities, in some cases, will be established for you by the material officer or higher authority, but in many instances you will have to consider the factors involved and make the decision yourself as to what comes first.

To become proficient at organizing and planning the work for your group will require experience, and, being human, you will make mistakes. The more you plan, though, the better you will be able to plan. And, by all means, profit by your experience and mistakes. There is a great difference between ten year's experience, and one year's experience repeated ten times.

ASSIGNING AND SUPERVISING WORK

As the senior I. C. Electrician on a large ship, after having organized and planned your workload, you would normally assign the job or jobs to the various circuit subgroup supervisors, and they in turn would assign the men in their subgroup to the specific jobs. This division means both the senior man and the subgroup supervisor must delegate some authority.

In delegating authority to others, always select the next senior below you if possible. Seniority is just as important going down the line as going up. Be certain that any man delegated authority clearly understands what is expected of him and what is to be accomplished. Delegating authority does not relieve the senior of the final responsibility for satisfactorily accomplishing the work.

When assigning the work, be fair to all. It is a natural inclination to favor certain individuals in preference to others, and it is important for the supervisor to realize and to control this natural tendency. Avoid assigning a man to all jobs of a specific type just because the man is more proficient in that particular phase of work. Distribute the work by rotating work assignments among the men in the subgroup so that each man will gain experience on all the IC equipment in that subgroup before he is assigned to another subgroup. Pair off experienced men with men of lesser experience. Give special consideration to job assignments for new men in the group, especially those who have just been assigned as strikers and have not attended the class A school. Always make sure these men are aware of the dangers involved regarding electrical circuits and equipment, before assigning them to any job regardless of how simple the job may be.

The Supervisor

As a subgroup supervisor under the senior I. C. Electrician you have the responsibility and the authority for the proper maintenance and repair of all circuits and equipment included in

your subgroup, and the efficient operation of the subgroup. To accomplish this, you have at your disposal time, materials, equipment, and men. The men, will use the time, materials, and equipment in a way that will either save or waste them. Many men (especially those who are inexperienced) of their own initiative, will not conserve materials to the utmost, operate or maintain equipment in a proper and safe manner, or put their time to the most productive use. Directing, guiding, and controlling the actions of your men, therefore, becomes your primary concern as a supervisor.

Effective supervision requires hard work, knowledge, and experience. In supervising the I. C. Electricians in your group you will have to practice sound leadership principles, as discussed in Military Requirements for Petty Officers 3 & 2 and Military Requirements for Petty Officers 1 & C.

You will have to continually keep a close check on the progress of the work assigned and be alert for slackness, confusion, and duplication of efforts. You will have to learn to give your men as much leeway on the job as the job, and their abilities, will allow. A common mistake among inexperienced supervisors is trying to do too much of the work themselves, thereby losing control of the actions of the other men in the group. You should be ready at all times, to lend a hand when necessary, of course, but keep in mind you are responsible for the actions of all the men in the group.

If, as a supervisor, you find you never seem to have enough time for such things as keeping an adequate check on the jobs assigned, planning, laying out and assigning work properly, and making periodic inspections of spaces and equipment, it may help you to do a little personal planning or analyzing of your own time. At the end of each day write down exactly what you did all day. Include jobs you actually performed yourself, time spent checking on other jobs, inspecting equipment and spaces, checking personnel on watch, etc. Do this for several days; then analyze the results. You may find that you are spending too much time doing nonsupervisory work, or work that someone else should be doing.

REPORTING EQUIPMENT STATUS AND WORK ACCOMPLISHMENT

The commanding officer must know the status of all machinery and equipment aboard his ship at all times. He is kept informed of this status by the heads of the departments, and they in turn are kept informed by the division officers. This requirement is according to Navy Regulations and is supposedly a routine matter; however no other single incident aboard ship has caused more embarrassment at levels than a change occurring in the status of a piece of machinery or equipment without the proper authorities being informed of the change. As an IC2 or IC1 you are probably already aware of this; however, it is also your duty to see that all men under you are aware of the importance of reporting any occurrence that may change the status or readiness condition of the IC equipment.

All men in the IC group should know what IC equipment is considered vital equipment and should be aware of the necessity of reporting immediately any failure or change in status of this equipment.

As the senior I. C. Electrician you must keep the division officer informed at all times as to the status of the IC equipment and the work being accomplished.

Maintaining an up to date work progress and equipment status chart in the IC shop or shops (fig. 2-2) can be helpful to all men in the IC group in keeping up with work accomplished and the status of the IC equipment. Such a chart can be made of plexiglass and kept up to date with a grease pencil. If you find it impracticable to show all jobs in progress on a chart of this type, show only the major jobs and the equipment out of commission.

WATCH SUPERVISION

Maintaining an alert and qualified watch at all times is of utmost importance. Personnel on watch are entrusted with the operation of the ship, and the safety of the ship, machinery, and personnel. Past records show instances of ship disasters such as collision, grounding, flooding, and fire—even loss of ship—that have been caused either directly or indirectly by improper performance of personnel on watch.

To be a qualified watch stander, a man must thoroughly understand what his duties on watch are, and be able to perform these duties proficiently. He must also be aware of his responsibilities and the extent of his authority while on watch and know exactly what is expected of him in any emergency.

As an IC1 or Chief I. C. Electricain you will have the initial responsibility for qualifying the

JOBS IN PROGRESS	MEN ASSIGNED	DATE STARTED	PERCENT COMPLETE %	DATE	INITIALS	EQUIPMENT OUT OF COMMISSION EQUIPMENT	DATE	INITIALS
OVERHAUL #1 SHAFT REV. TRANS.	KELLY-IC2 BROWN-IC3	1-10-62	75	1-10-62	CK	SHAFT REV. TRANS. #1	1-10-62	CK
QUARTERLY INSPECTION FWD. GYRO	SIMON-IC1 MILLER-IC3	1-10-62				FWD. GYRO	1-10-62	HS
						6MC	1-10-62	DK

Figure 2-2.—IC work progress and equipment status chart. 40.2

watch standers in the IC group. You will have men on watch in spaces where improper action, or no action on their part, could vitally affect the operation and control of the ship, or the safety of the ship, her machinery, and personnel. Your men on watch will have direct or indirect control over equipment or circuits associated with ship control and navigation, fire control and gunnery, alarm and warning systems, radar and sonar, communications, and damage control.

In qualifying the IC watch standers, you will find it helpful to make up qualification lists for the various watches. These lists can be posted at the watch stations concerned and should include all duties of the watch, what knowledge the man must have, what functions he should be able to perform, and what action he should take in emergencies for the particular watch.

After a man has stood a number of instruction watches under other qualified watch standers, you should then check him out, using the qualification list as a guide. If the qualifications call for such things as lighting off, securing, or shifting machinery or equipment you should have the man actually perform these operations in your presence before listing him as a qualified watch stander. Although the division or electrical officer may, on some ships, sign a form stating a certain man is qualified for a particular watch, remember he is taking your word as to whether the man is qualified or not.

In addition, the best qualified watch stander in your division is of no value to the division, or the ship, if he is not on station and alert. It is important, therefore, that you, as the leading or senior I. C. Electrician, check your men on watch frequently to ensure they are on station and alert, and are not engaging in any activities that might hinder them from carrying out the duties of the watch.

INSTRUCTION AND TRAINING

As an IC1 or Chief I. C. Electrician you will be concerned with instructing and training the lower rated men in the group, in both their military and technical requirements for advancement in rating.

Training methods, training schedules and bills, and shipboard instruction and training in general are discussed in Military Requirements for Petty Officers. In addition to Military Requirements for Petty Officers, you will also find the Manual for Navy Instructors (NavPers 16103) and Shipboard Training Manual (NavPers 90110) valuable sources of information concerning instruction and training.

Training starts for the Navy enlisted man the day he enters boot camp and continues throughout his naval career. After recruit training he may receive further formal training in class A, B, and C services shools. On board ship he receives team or unit training in casualty and damage control. In addition, he is continually receiving formal or informal on-the-job training and instruction. It is in this on-the-job training, and informal day-to-day training and instruction that you will be vitally concerned.

The prime objective of Navy enlisted training is to develop the civilian enlistee into a petty officer skilled in the technical requirements of his rating, aware of his responsibilities as a leader in the naval service, and informed of his duties as a citizen of the United States. The first step towards accomplishing this objective occurs in recruit training, but you, as a senior

petty officer, through your formal and informal on-the-job training and instruction, and by your own personal example, can accomplish a lot in all three areas indicated in this objective.

TECHNICAL TRAINING

On-the-job technical training for the IC group must be organized and carried out with the following major objectives in mind:

1. To train all men in the IC group so as to continually increase their technical knowledge and improve their skills in the duties of the rating.
2. To train as many men as possible in the group on all the IC equipment, so as to have at least one qualified relief for any man in the group.
3. To train each man in the group, to the extent possible, in his professional requirements for advancement to the next higher rate, by the time he is eligible for advancement.

To effectively accomplish these objectives requires some planned and organized formal instruction, utilizing all petty officers in the group as instructors, and continuous day-to-day informal instruction whenever the opportunity arises. For maximum results in this informal training and instruction every man in the group must be aware of his responsibility for instructing his subordinates.

Certain records are necessary for proper administrative control of training. These records will be discussed in the next chapter.

An effective program for technical training is to have the petty officers in each subgroup give lessons on the equipment they operate and maintain, in their respective subgroups, both to their own subgroup and the other subgroups. For example, one of the men in subgroup No. 1 (fig. 2-1) would give a lesson on the automatic telephone switchboard to his own subgroup, and at later dates, he or another man in the automatic telephone gang would give this same lesson to the other subgroups. As the same lesson will be given many times and not always by the same instructor, care should be taken to ensure that proper lesson plans are made up and maintained for all the IC equipment in each subgroup.

This program, if carried out on a continuing basis, will familiarize the maximum number of men with all the IC equipment.

The greater part of a man's practical experience, however, is gained on the equipment in the subgroup to which he is assigned. Broadening this practical experience necessitates rotating assignments of the men among the different subgroups. In rotating subgroup assignments consider the individual man, as far as possible, rather than having a policy of rotating all men after a specific length of time. Consider such factors as: what practical factors and experience the man must have before being eligible to advance to the next rate; how much time does he have before this advancement; and has he gained all the experience possible, or necessary, in his present subgroup. Rotating assignments of the man in this manner ensures that a man will get the practical experience he needs for advancement and also allows the man with above-average ability, or the conscientious man, to gain experience on all the IC equipment much quicker than a definite time rotation plan. You will not always be able to rotate assignments to satisfy the requirements of all the men, and there will be times when men will have to be rotated strictly for the good of the group or the ship. In the majority of cases though, rotating a man according to his needs and abilities will also be to the group's and ship's advantage.

Practical experience on IC equipment will be limited to the equipment on your ship; however, you can familiarize the men, to some extent, with other IC equipments and systems. This can be done by having petty officers in the group, who have had experience on different types of ships, give lessons on IC equipment not installed aboard your own ship.

Further, your ship may often be in port with other ships of various types, and you may be able to utilize your training time by visiting or attending a technical training lesson one of these ships. In doing this, the men get to see the actual equipment and how it operates.

LEADERSHIP TRAINING

All petty officers in the IC group will receive formal leadership training under the ship's leadership program. It will be your responsibility to ensure that every petty officer in the group gets a chance to practice leadership. By delegating some of your authority, and following the chain of command within the group, you give them this practice.

You must be available at all times to discuss or assist them with their leadership problems, but most important, you must set for them the best possible example.

CITIZENSHIP TRAINING

Citizenship training for the Navy enlisted man is designed to develop within the enlistee a better understanding of the fundamentals of American democracy and a greater appreciation for the American way of life. During recruit training all recruits attend lectures on topics such as the fundamentals of democracy, the Constitution, contrasts between American democracy and totalitarian forms of government, and the United Nations. Most of your men will also have been exposed to some training along these lines before entering the Navy. Very few of your men, though, will have given much serious thought to citizenship subjects or his duties as a citizen before he reports to you for duty in the IC group. Your major objective will be to start him thinking seriously on these subjects. Certainly, no organization in the world offers a better opportunity for doing this than the U. S. Navy. Most of your men, as they see more of the world and become more mature, will eventually become interested in these subjects on their own. With your help and guidance they get started much earlier.

You are already aware of the tremendous amount of nonprofessional material read by Navy men onboard ship. If you can get a man to devote even a small percent of this reading time to books from the ship's library dealing with subjects concerning citizenship, you have a start in the right direction.

Frequently, the technician you have trained is lost to civilian industry. If, however, at the same time you have started this technician on the road to becoming a responsible citizen of our Country, you have more than compensated for this loss.

CHAPTER 3

RECORDS AND REPORTS

Records are those papers required to be compiled and retained on board ship for prescribed periods of time for reference in administrative and operational matters. Reports are summaries or narratives submitted to interested activities to assist in forming policy, controlling operations, evaluating performance, and maintaining historical records. Some reports are required to be submitted at set intervals, and are generally referred to as recurring reports. Other reports are submitted only on the occurrence of a given situation and are referred to as one-time reports.

The engineer officer is responsible for maintaining various records and submitting various reports concerning the engineering department. Most of these records and reports are required by higher authority such as type or fleet commanders, BuShips, and CNO. Frequently, however, the engineer officer prescribes additional records which he feels are essential for effective administration of the department or for proper maintenance, operation and repair of the machinery and equipment.

As the leading I.C. Electrician you will be directly concerned with engineering records and reports relating to the I.C. equipment. As a senior petty officer in the engineering department you should also be generally familiar with other engineering records and reports.

This chapter will discuss engineering records and reports that will concern you and are in addition to those covered in I.C. Electrician 3 (NavPers 10555-A) and I.C. Electrician 2 (NavPers 10556-A).

ADMINISTRATIVE RECORDS

Among the administrative records maintained by the engineering department are casualty and damage control exercise records, repair parts requisitioning records, blueprint and manufacturer's instruction book files and index, personnel data records, and division training records. You will be directly concerned with maintaining the training records for the I.C. group.

TRAINING RECORDS

Training records are necessary to indicate to those responsible for training how much training has been done, and how much remains to be done. In an effort to eliminate all but essential training records, and to standardize these records to the extent possible for all ships, four general record forms have been developed. These forms may be used for scheduling and recording all shipboard training, and are discussed in Military Requirements for PO 1&C (NavPers 10057) in more detail in NWP 50, chapter 10. If you haven't already done so, it is suggested that you study the Training Responsibility chapter in Military Requirements for PO 1&C at this time. The training records discussed in this chapter that will concern you most are the Group Record of Practical Factors and the Individual Training Record.

The requirement for the Group Record of Practical Factors is based primarily upon the need for the division senior petty officer and higher authority to know exactly on what equipment each man in the division has had experience and is qualified, and on what equipment he is yet to gain experience and become qualified. Any record listing all the I.C. equipment and systems on your ship, showing the dates that each man becomes qualified on the systems and equipment concerned, should fullfill your group record requirement relating to professional practical factors. You may find it to your advantage to keep a group record on the type 2 general record form similar to figure 3-1 rather than supplement the NavPers 760 Record of Practical Factors as described in Military Requirements for PO 1&C. The group record (fig. 3-1) should be kept up to date by

GENERAL RECORD (Type II)
OPNAV FORM 1500-31 (10-60)

PERIOD COVERED: FROM 1 Jan 62 TO Continuous

TITLE

EQUIPMENT AND WATCH QUALIFICATIONS--IC GROUP

COLUMN CAPTIONS	ADAMS-IC1	BAKER-IC2	COLE-IC2	DEAN-IC3	ECKERT-IC3	FRANK-IC3	GOOD-ICFN	HINES-ICFN	INGLE-ICFA
Sound powered telephones	1-15-62	2-1-62	2-1-62	1-15-62	1-15-62	1-15-62	4-1-62	1-15-62	4-1-62
Automatic telephones	1-15-62		2-1-62		1-15-62			4-1-62	
Call bell systems	1-15-62	2-1-62	1-15-62	1-15-62	1-15-62	1-15-62	4-1-62		
Intercom systems	1-15-62	2-15-62	1-15-62	3-1-62	1-15-62		4-1-62		
C.A. announcing systems	1-15-62	2-15-62	2-1-62		1-15-62				
Portable announcing systems	1-15-62	2-15-62	2-1-62	4-1-62	1-15-62	2-1-62			
Recorder and reproducing systems	1-15-62	2-15-62	2-1-62		1-15-62	2-1-62			
Motion picture equipment	1-15-62	1-15-62	1-15-62	4-1-62	1-15-62	1-15-62			
Main engine and steering control equipment	1-15-62	2-15-62	1-15-62		1-15-62				
Gyrocompass equipment	1-15-62	2-1-62		4-1-62	4-1-62				
Underwater log equipment	1-15-62	2-1-62	3-1-62	4-1-62	4-1-62				
Dead reckoning equipment	1-15-62	2-1-62	3-1-62		4-1-62				
Alarm and warning systems	1-15-62	2-1-62	2-15-62	1-15-62	1-15-62		3-2-62		
Indicating systems	1-15-62	1-15-62	2-15-62	2-1-62	1-15-62				
Communication console equipment	1-15-62		3-1-62		1-15-62	4-1-62			
I.C. records and reports	1-15-62	3-1-62	3-1-62	4-15-62	4-15-62	4-1-62			
Qualified motion picture operator	1-15-62	1-15-62	1-15-62	1-15-62	1-15-62	1-15-62			
Qualified IC room watch	1-15-62	1-15-62	1-15-62	4-1-62	4-15-62	1-15-62			
Qualified gyro electrician	1-15-62	1-15-62		4-1-62	4-15-62				
Qualified duty I.C. Electrician	1-15-62	1-15-62	1-15-62	4-1-62	4-15-62	1-15-62			
Qualified Division duty P.O.	1-15-62								
Qualified S/S switchboard watch	1-15-62	1-15-62	1-15-62	1-15-62	1-15-62				
Qualified division damage control P.O.	1-15-62	1-15-62	1-15-62	1-15-62	1-15-62				
Qualified repair party I.C. Electrician	1-15-62	1-15-62	1-15-62	1-15-62					

Figure 3-1.—Equipment and watch qualifications—IC group. 243

the senior I.C. Electrician. When, in your opinion a man has had sufficient experience on a particular system or piece of equipment, fill in the date in the appropriate block on the record. Initialing the block will not be necessary as you will be keeping the record personally. Information on this record will be a major factor in determining when to rotate work assignments of your men.

The type 2 general record form provides spaces for 9 men front and back. However, if necessary these spaces may be divided to accommodate 18 men.

Your individual I.C. training record may also be recorded on the type 2 record in the same manner as in figure 3-1. List the lessons to be given on the left margin of the record. The instructor giving the lesson fills in the date and his initials for each man as he attends a lesson.

MAINTENANCE AND REPAIR RECORDS AND REPORTS

Effective maintenance and repair of all machinery and equipment is a major factor contributing to battle readiness of a ship. The establishment of a realistic schedule of tests and inspection and ensuring that this schedule is carried out on a continuing basis are the most important factors contributing to an effective maintenance program.

PERIODIC TESTS AND INSPECTIONS OF I.C. EQUIPMENT

As the leading I.C. Electrician you will be responsible for carrying out the preventive maintenance program for the I.C. equipment. This requires you to ensure that all periodic tests and inspections of I.C. equipment, as prescribed by the BuShips Technical Manual or other authority, are properly underway. An effective method of accomplishing this result is by use of preventive maintenance checkoff cards (fig. 3-2). These cards fit the McMillan type binder that is used for the material history cards. They are available at most district printing and publication offices or can be made up on repair ships or tenders. Both sides of the cards are printed; the daily card is good for one year and the other card is good for two years.

A checkoff card is filled out for each unit of I.C. equipment requiring periodic tests and inspections, and the man who actually made the test or inspection initials the card in the appropriate block. The specific tests and inspections to be performed are filled in on a blank utility card (NavShips 532, fig. 3-3) that fits the McMillan binder. This card is inserted in the binder adjacent to the checkoff card for the equipment concerned, and shows the man initialing the checkoff card exactly what he is certifying he has done. You will have various equipments, such as motors, generators, controllers, intercom units, and portable announcing units that may not be identical units, but will require the same periodic tests and inspections. The checkoff cards for these units may be grouped together in the binder with one appropriate NavShips 532 card in the front of the groups (fig. 3-4).

You may also incorporate your weekly tests of safety devices in the binder. List the safety devices to be tested, and any testing instructions necessary, on a NavShips 532 card and place it in the binder along with a checkoff card labeled "safety devices."

For small ships, one McMillan binder will accommodate enough checkoff cards for all the I.C. equipment, and perhaps enough for the entire "E" division. On large ships, however, you may need a binder for each subgroup supervisor in the I.C. group.

As the senior or leading I.C. Electrician you may be required each week to sign a statement for the electrical officer or engineer officer, certifying all required I.C. tests and inspections have been made. Up-to-date records of this type will show you whether these tests and inspections have been made. They will also show you when and by whom they were made.

REPAIR RECORDS AND PROCEDURES

Ships cannot operate continuously without repairs. Derangements, deterioration, and other defects or deficiencies will occur to the machinery and equipment despite the best preventive maintenance program. Such defects and deficiencies as are within the capacity of the ship's force to correct are repaired as soon as possible after discovery. Repairs beyond the capacity of the ship's force are accomplished by a repair activity either afloat or ashore.

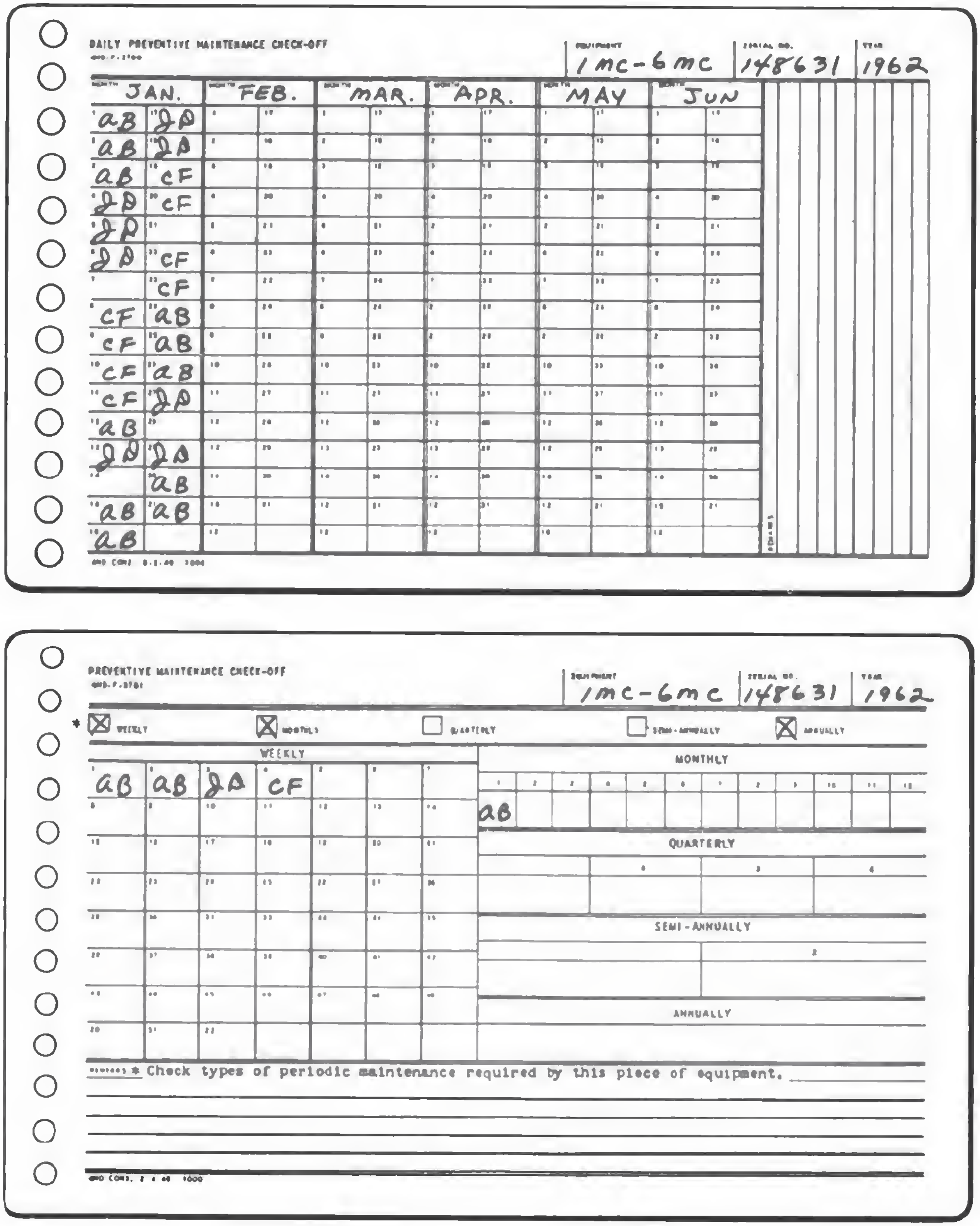


Figure 3-2.—Sample preventive maintenance checkoff cards.

40.3
40.4

TESTS AND INSPECTIONS--1MC-6MC ANNOUNCING SYSTEM

DAILY:
1. Visually inspect settings of all controls and switches.
2. Check blown fuse indicators.
3. Test alarms.

WEEKLY:
1. Test all tubes.
2. Test and shift amplifier channels and oscillators.
3. Test alarms from all contact makers.
4. Make speech transmission from all transmitter stations.

MONTHLY:
1. Clean control racks and amplifier panels.
2. Inspect all relay contacts and clean as necessary.
3. Visually inspect all interior wiring for broken leads and loose connections.
4. Inspect all resistors for discoloration.
5. Inspect each transmitter station for watertight integrity.
6. Ground test transmitter stations and loudspeakers (USE OHMMETER).

ANNUALLY:
1. Shut down and thoroughly clean system.
2. Tighten all connections.

40.5

Figure 3-3.—Sample NavShips 532 card for 1MC-6MC equipment.

Availabilities

A ship may not informally, on her own, come alongside a repair ship or tender or enter a naval shipyard for repairs. The control and disposition of a ship is at all times a function of certain operating commands. Thus when a ship needs outside repair, the type commander, or higher authority, assigns the ship an "availability" at a repair activity. The term "availability" is defined by Navy Regulations as the period of time assigned a ship by competent authority for the uninterrupted accomplishment of work at a repair activity. The three major types of availabilities are regular overhaul, restricted, and technical.

REGULAR OVERHAUL.—A regular overhaul availability is for the accomplishment of general repairs at a naval shipyard or other shore-based repair activity. The length and interval between regular overhauls vary for different type ships and are established upon recommendations by the fleet and type commanders.

RESTRICTED AVAILABILITY.—This type of availability is assigned for the accomplishment of specific items of work by a repair activity, with the ship present.

TECHNICAL AVAILABILITY.—A technical availability is assigned for the accomplishment of specific items of work at a repair activity, with the ship not present.

Repairs and Alterations

Maintenance work accomplished on all shipboard machinery and equipment may be grouped into three general categories: (1) repairs, (2) alterations, and (3) alterations equivalent to repairs.

REPAIRS.—A repair is defined as the work necessary to restore a ship or article to serviceable condition without change in design, materials, number, location, or relationship of the component parts. Repair work items are determined by the ship's force. Major items

TESTS AND INSPECTIONS INTERCOM SYSTEMS

WEEKLY: Ground test circuits

QUARTERLY: Inspect units on exposed stations for corrosion and watertight integrity

SEMIANNUALLY:
1. Check tubes and switches
2. Clean contacts and equipment
3. Check for loose connections
4. Make transmission test

40.5

Figure 3-4.—Sample NavShips 532 card for intercom units.

are approved for accomplishment by the ship's commanding officer if the work can be accomplished by the ship's force, or the type commander concerned if the work cannot be accomplished by the ship's force.

ALTERATIONS.—An alteration is defined as any change in the hull, machinery, equipment, or fittings that involves a change in design, materials, number, location, or which involve a change in the relationship of the component parts of an assembly regardless of whether any such change is undertaken separately from, incidental to, or in conjunction with repairs.

Requests for alterations may originate from the technical bureaus, from the forces afloat, or from the Chief of Naval Operations. In any case the technical bureau having cognizance of the equipment concerned approves the alteration provided the alteration does not affect the military characteristics of the ship. Alterations under the technical cognizance of BuShips are referred to as ShipAlts. Alterations affecting the military characteristics of a ship are referred to as NavAlts, and must be approved by the Chief of Naval Operations.

ALTERATIONS EQUIVALENT TO REPAIRS.—An alteration is considered equivalent to a repair when any of the following conditions exist:

1. It involves the use of different materials from standard stock, which have been approved for similar use.

2. Worn or damaged parts requiring replacement are replaced by those of later and more efficient design previously approved by the bureau concerned.

3. The alteration consists of strengthening of parts which require repair or replacement, to improve the reliability of the parts and of the unit, but no other change in design is involved.

4. Minor modifications are made that involve no significant changes in design or functioning of equipment, but are considered essential to prevent reoccurrence of unsatisfactory conditions.

Alterations equivalent to repairs may be approved and authorized by type commanders without reference to the bureau concerned when they do not involve increase in weight or vertical moment. They are financed and administered in the same manner as repairs, except that their completion is reported to the bureau concerned.

WORK REQUESTS

The terms, work requests, and job orders are often used interchangeably. This is not technically correct as the two terms have different meanings. Work requests are prepared by a ship and forwarded through proper channels to a repair activity. When the work request has been approved by the repair activity, it becomes a job order and a job order number is assigned. When this number is assigned, the work request becomes an actual job order to repair personnel of a repair ship or tender. Naval shipyards, however, issue their own form of job orders when the work requests have been approved.

Preparing and Processing Work Request

After a ship is assigned a regular overhaul or restricted availability, the ship concerned must prepare all work requests early enough for them to be processed and reach the repair activity well in advance of the ship's arrival.

Each department head is responsible for ensuring that all work requests for his department are properly prepared and submitted to the commanding officer. After review by the department head and approval by the commanding officer, the requests and required copies are forwarded via the squadron commander or other appropriate authority to the type commander. The requests are carefully screened by staff officers handling material and maintenance before the type commander's approval. Usually most of the requests are approved. Some may be disapproved, deferred, or reworded for various reasons. As the type commander is responsible for administering the funds for the availability, some requests may be disapproved by him for lack of funds or reworded so that the ship's force will accomplish most of the work. Frequently a ship is requested to furnish more detailed information on certain work requests before approval. The number of work requests approved by the type commander will depend largely upon how well the requests have been prepared by the ship and whether they follow established policies and procedures.

Upon completion of screening and the type commander's approval, the work requests are forwarded to the repair activity.

Preparing the rough work requests for necessary repairs to the I.C. equipment will be one of your duties as leading I.C. Electrician. The engineer officer does not have the time to rewrite work requests, or even to check every detail of every request submitted. It is very important, therefore, that your rough work request contain all accurate data and information necessary concerning the need for, and accomplishment of, the repair.

The preparation of work requests for an availability is relatively simple if the Current Ship's Maintenance Project (CSMP) cards are complete and up to date. The repair record cards (NavShips 529) included in the CSMP furnishes a list of repairs to be accomplished and includes most of the necessary data and information needed for preparing the work requests.

Work request form (NavShips 4757) as shown in figure 3-5 is at the present time the recommended form for use by all ships. This form was developed primarily for requesting repairs at a naval shipyard but can be used for other repair activities. Continuation sheets (NavShips 4757-1) are also available for any additional data or information necessary for which space on the basic form is insufficient. Directions for preparing both the basic form and continuation sheets are furnished with the forms.

Before a work request is finally approved by a repair activity and a job order issued to accomplish the work, considerable preplanning is done. This is especially true at naval shipyards. Planners and estimators must prepare cost estimates for each repair. Mandays for each shop involved to accomplish the work, and the amount and cost of all material necessary, are estimated. A specific amount of money from the total funds available to the ship for the availability is then allocated to the repair concerned. It is obvious that these estimates would be impossible to make from incomplete or inaccurate work requests. You will find it helpful to keep the repair activity planner in mind when preparing a work request,

RE-READ DIRECTIONS OFTEN – "COMPLETE" REQUESTS GET MORE MAINTENANCE PER DOLLAR OR PER MAN-DAY

1. SHIP (NAME, TYPE, HULL NO.) U. S. S. SEAWAY (CLG 18)

2. DATE FIRST WRITTEN 1-15-62

3. WORK REQUEST SER. NO.

4. COMPONENT, SYSTEM, ETC (Item to be worked on)
400 CYCLE MOTOR GENERATOR SET #1

5. PRIORITY - URG (A) – DES (B) – DEPT. PRI. NO. COG.
SHIP'S
TYCOM'S / INSURV'S

6. WORK REQUESTED (Specify work to be done and/or symptoms of maloperation, etc.)
REMOVE GENERATOR SECTION OF MOTOR-GENERATOR SET #1 FROM SHIP. REWIND 3 PHASE STATOR. CLEAN, DIP, AND BAKE ROTOR (REVOLVING FIELD) WINDING. REINSTALL ON BOARD AND LOAD TEST.

INTEGRATED NUMBER

7. LOCATION
COMPARTMENT(S) B-304-E

DECK	FRAME(S)	SIDE
3	112	P

8. JUSTIFICATION AND/OR HISTORY
STATOR WINDING BURNED OUT DUE TO MOISTURE. ROTOR WINDING HAS LOW GROUND READING.

9. STANDARDS OF WORK/CLASS OF REPAIRS
REWIND STATOR

10. REPAIR PARTS KNOWN OR EXPECTED TO BE NEEDED
2 BALL BEARINGS FSN H3310-106-5084

11. NAME PLATE INFORMATION
GENERATOR DATA:
VOLTS - 120 AC
PHASE - 3
K.W. - 5
CYCLES - 400
C I D NO 1089072

12. BASIC PLAN NO(S) AND/OR APPLICABLE INSTR. MANUAL (NAVSHIPS NO. IF ASSIGNED)
NAVSHIPS 363-0908
AVAILABLE ABOARD? YES X NO

13. ASSISTANCE SHIPS FORCE WILL GIVE
ASSIST WITH AND WITNESS TEST

14. WORK PROGRESSED & INSPECTED (FOR SHIP) BY
A.B. SEA - LT (JG)
D.E. EFF - ICC
G.H. EYE - IC1

15. REQUEST DRAFTED BY
D.E. EFF - ICC

16. REQUEST REVIEWED & APPROVED BY (FOR SHIP)

17. CHECK IF CONTINUATION SHT ADDED ☐

18. FLEET SCREENING ACTION

Ship	Ve	Tycom	
☐	☐	☐	SHIPYARD ACCOMPLISH
☐	☐	☐	TENDER OR REPAIR SHIP ACCOMPLISH
☐	☐	☐	SHIPS FORCE – (TENDER OR R/S) (YARD) ASSIST
☐	☐	☐	ACCOMPLISH AS ALT EQUIV TO REPAIR
☐	☐	☐	SHIP TO SHOP
	☐	☐	YARD OPEN & INSPECT – ADVISE TYCOM – PROCEED WITH MINIMUM REPAIRS
	☐	☐	DISAPPROVED OR DEFERRED
	☐	☐	OTHER (SPECIFY) OR REMARKS

19. THIS SPACE FOR REPAIR ACTIVITY'S USE
JOB ORDER NO. LEAD CODE
ESTIMATED COST (DATE OF EST – ARRIVAL (MINUS) (PLUS) DAYS)
TOTAL M/D | TOTAL DOLLARS $ | LABOR $
MATERIAL $ | OVERHEAD
PREARRIVAL AND/OR ARRIVAL CONFERENCE ACTION – REMARKS
DIRECT CHARGES TO CUSTOMER'S FUNDS
TOTAL $ | TOTAL M/D
NON REIMB. MAT'L (APA) $ | MATERIAL $ | LABOR $

11	17	23	26	31	35	38	41	51	56	57	64	67	68	71	72	74	99	CODE 300	Other Shops	TOTAL

WORK REQUEST NAVSHIPS 4757 (REV. 8-60)

15.4

Figure 3-5.—Sample rough work request.

and after you complete the request consider the following:

1. Is the work requested (block 6, fig. 3-5) specific enough in detail for a shop planner to take this information plus the accurate nameplate data (block 11) and estimate fairly accurately the man-days required to complete the repair?

2. Could he also estimate all materials required for the repair, from the plans and/or instructions manuals (block 12) and repair parts needed (block 10)?

3. Will your description of ship's force assistance (block 13) along with the information in block 6 enable him to determine the different shops involved, and to what extent they will be involved, to complete the repair?

Frequently, ships are granted availabilities at repair activities on rather short notice, or availability dates may be advanced due to changes in operation schedules or other reasons. In view of this, it is advisable to prepare your work requests as early as possible after the need for the repair is evident. Establish a policy of preparing work requests at the same time the repair record card is filled in for the CSMP and you will never be rushed to get your requests in on time for an availability.

Progress of Work

One of your most important duties during an availability will be keeping an accurate check on the progress of all repair jobs on the I.C. equipment and keeping the division officer or other authority informed of this progress. Progress charts are usually made up on the ship for each department at the start of the availability. These charts show all jobs in progress, date started, percent completed, and are kept up to date by the ship's force. Keeping an accurate check on the progress of the I.C. repair jobs will require you to check frequently all jobs in progress aboard the ship and make periodic visits to all shops concerned at the repair activity.

Inspection Duties

The inspection of work being done by a repair activity for a ship is the responsibility of both the repair activity and the ship. The repair activity should require such inspections to be made as will ensure the proper execution of the work and adherence to prescribed specifications and methods. The ship should make such inspections as may be necessary to determine if the work is satisfactory, both during its progress and when completed.

You will most likely be designated ship inspector on all I.C. repair requests (block 14, fig. 3-5), and will be called upon by the repair activity to witness tests, inspect completed jobs, or perhaps to sign off job orders for completed jobs. Before signing any job order as being completed, or reporting the job completed to higher authority, always make sure the work has been satisfactorily completed as stated in the job order. Inspect, and test if necessary, the job yourself, and also ensure that any required tests by the repair activity have been made satisfactorily.

If, in your opinion, unsatisfactory work is being done or required tests are not being conducted, report the details to your division or engineer officer. He will take up the matter with the appropriate repair activity authorities.

Supplementary Work Requests

It is sometimes necessary to prepare supplementary work requests to include repairs that become evident subsequent to the submission of the original repair requests. These additional repairs may be the result of recent voyage casualties or of conditions discovered during tests and inspections by the repair activity. Usually, supplementary work requests are submitted to the repair activity via the type commander and processed in the same manner as the original repair requests.

Requests for Technical Availability

A technical availability, as mentioned previously, is assignment to a shore-based repair activity for work, with the ship not physically present. The most common type of technical availabilities involves shop work that is beyond the capacity of forces afloat. Technical availabilities are also used to some extent for authorizing the sending of technical personnel aboard ship for inspection of trouble or casualties, to give advice and make minor repairs.

Procedures for submitting a request for technical availability are prescribed by type commanders. Essentially, the request is a letter from the ship's commanding officer to a repair activity, via the type commander, requesting that a technical availability be granted

the ship for the accomplishment of repairs beyond the capacity of forces afloat to accomplish.

RECORDS AND REPORTS FOLLOWING REPAIRS

As early as possible after repairs and alterations, ship's plans, publications, and records affected should be brought up to date, and the required reports submitted. Normally, when a ship undergoes repairs at a naval shipyard, any corrections necessary to plans, blueprints, damage control, and ship information books, are made by the repair activity and delivered to the ship concerned upon completion of the availability or as soon thereafter as possible.

Following any repairs and alterations to the I.C. equipment, whether accomplished by a repair activity or ship's force, you will be concerned with making appropriate entries on the CSMP and material history cards and preparing the rough failure reports to be submitted to BuShips.

Equipment Failure Reports

A Report of Equipment Failure form (NavShips 3621, fig. 3-6) must be submitted to BuShips as soon as practicable after the accomplishment of any repair to installed shipboard machinery or equipment (except electronic) under the cognizance of BuShips. This form replaces the old Material Analysis Data form and is designed to aid the bureau in evaluating the performance and reliability of machinery and hull equipment.

An instruction sheet is furnished with the forms. Read these instructions carefully before preparing the form. List federal stock numbers for any parts or material referred to if available, and make your remarks and recommendations as specific and clear as possible. If the cause of failure is unknown, a design deficiency is suspected, or a recommendation for further study by the bureau is requested, all evidence of the failure (damaged parts, etc.) must be kept for 60 days after the report is submitted or until disposal instructions are received from the bureau. Failure reports are not required for routine maintenance repairs unless there is reason to believe that conditions other than normal wear and tear exist.

Electronic Failure Reports

Failures to electronic equipment at present are to be reported in accordance with BuShips Instruction 10550.73. An Electronic Equipment Failure/Replacement Report (fig. 3-7) and Electronic Equipment Operational Time Log (fig. 3-8) are to be submitted upon failure to selected equipment only. At the present time no I.C. equipments are included as selected equipment. Additions and deletions will be made from time to time to the list of selected equipments, and some I.C. equipment may be included in the near future.

Electronics Installation Record

The Electronics Installation Record (NavShips 4110, fig. 3-9) furnishes a complete and up-to-date inventory of all electronic equipment aboard each ship to interested fleet and shore activities. It furnishes BuShips a current record of shipboard electronic installations and serves as a means of informing the CNO, fleet and type commanders, the electronics supply office, and naval shipyards of the electronic installations in the fleet. In addition it serves as a basis for determining Electronics Repair Parts Allowance Lists (ERPAL).

The responsibility for keeping the record up to date and keeping the interested activities informed, rests with the ship concerned. However, repair activities may be requested to assist the ship in bringing the record up to date after overhaul.

For reporting purposes on the NavShips 4110 form, the ship's electronic equipment is divided into 8 major categories. Category 7 is intercommunication equipment, which includes the following equipment:

1. Shipboard announcing system amplifiers and loudspeakers
2. Intercom units
3. Communication console equipment
4. Sound recorders
5. Record players
6. Portable announcing and public address systems
7. Ship's entertainment systems
8. Sound-powered telephone amplifiers.

Instructions for preparing, revising, and submitting NavShips 4110 are contained in NavShips Publication 900,135. Reports on category 7 equipment are now submitted directly to the Electronics Supply Office rather than BuShips as previously.

REPORT OF EQUIPMENT FAILURE
NAVSHIPS 3621 (Rev. 6-59)

REPORT BUSHIPS-9120-1

1. SHIP TYPE	2. HULL NUMBER	3. DATE OF FAILURE (MONTH, DAY, YEAR)	4. DATE OF LAST FAILURE (MONTH, DAY, YEAR)
AKA	80	3-22-62	12-1-61

NAME OF FAILED COMPONENT: GENERATOR IC MOTORGENERATOR SET #2

5. COMPONENT ALLOWANCE GROUP NUMBER: 563

6. COMPONENT IDENTIFICATION NO. (CID): 18107003

COMPONENT MANUFACTURER'S NAME: BURKE ELECT. CO.

7. MANUFACTURER'S SERIAL NUMBER: 149514

8. NUMBER OF MAINTENANCE CHECKS SINCE LAST FAILURE	9. DID COMPONENT FAIL IN OPERATION?	10. OPERATIONAL HOURS SINCE COMPONENT LAST FAILED.
20	☒ YES ☐ NO	1500

CAUSE OF FAILURE (CHECK ONE)

1 ☐ BROKEN OR CRACKED PART	5 ☐ FAILURE OF WELD.	9 ☐ LOOSE CONNECTION	13 ☐ LEAK
2 ☐ EXCESSIVE PART CLEARANCE	6 ☐ LACK OF LUBRICATION	10 ☐ INSULATION FAILURE	14 ☐ FUNGUS
3 ☐ FAILURE OF CONTROL	7 ☐ IMPROPERLY INSTALLED	11 ☐ WATER	15 ☐ CORROSION
4 ☐ FOREIGN MATTER	8 ☐ EXCESSIVE HEAT	12 ☐ VIBRATION	16 ☒ UNKNOWN

17 ☐ OTHER (SPECIFY)

PART DATA

NAME OF PART THAT FAILED	MATERIAL OF WHICH PART IS MADE	HOURS OPERATIVE	PART NO. (USE ONLY ONE) FEDERAL STOCK NO. BUREAU PLAN OR PIECE NO. OR MCF NO.
COLLECTOR RING ASSEMBLY	BRONZE	1500	H 5977-101-1760

REMARKS AND RECOMMENDATIONS

Give description of failure, elaborate on cause and/or remedy as appropriate. Give recommendations to prevent recurrence

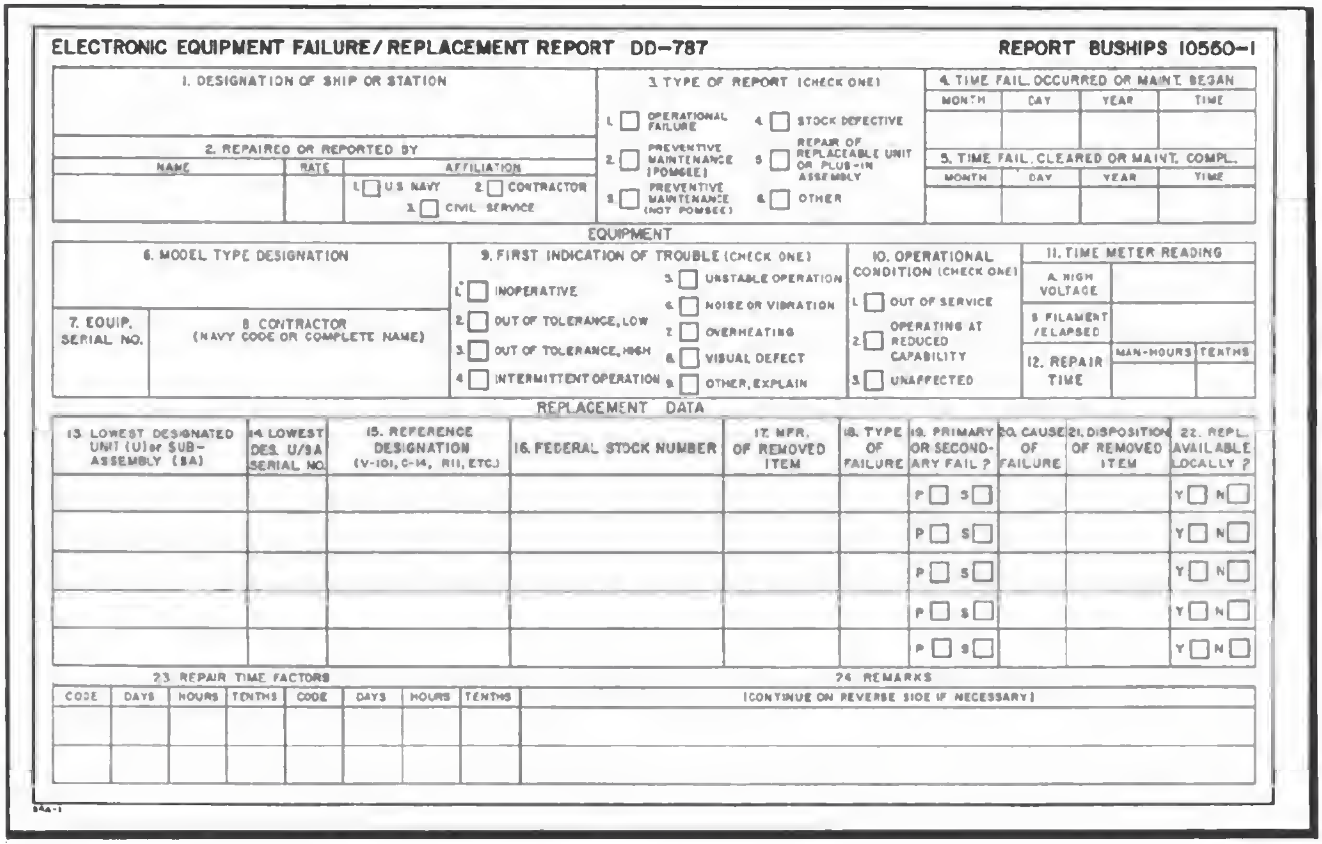
CENTER COLLECTOR RING GROOVED AND PITTED OVER AN AREA SPANNING 120 DEGREES REQUIRING REPLACEMENT OF COLLECTOR RING ASSEMBLY. IDENTICAL FAILURE OCCURRED TO #1 M.G. SET 6-3-61. STOCK NO. FOR BRUSHES INSTALLED IS H 5977-206-1871. REQUEST FURTHER STUDY AND RECOMMENDATIONS.

SIGNED	DATE

G11135

8.110

Figure 3-6.—Sample equipment failure report.


ELECTRONIC EQUIPMENT FAILURE/REPLACEMENT REPORT DD-787 REPORT BUSHIPS 10560-1

1. DESIGNATION OF SHIP OR STATION

2. REPAIRED OR REPORTED BY

NAME	RATE	AFFILIATION
		1. U.S. NAVY 2. CONTRACTOR 3. CIVIL SERVICE

3. TYPE OF REPORT (CHECK ONE)
1. OPERATIONAL FAILURE
2. PREVENTIVE MAINTENANCE (POMSEE)
3. PREVENTIVE MAINTENANCE (NOT POMSEE)
4. STOCK DEFECTIVE
5. REPAIR OF REPLACEABLE UNIT OR PLUG-IN ASSEMBLY
6. OTHER

4. TIME FAIL. OCCURRED OR MAINT. BEGAN

MONTH	DAY	YEAR	TIME

5. TIME FAIL. CLEARED OR MAINT. COMPL.

MONTH	DAY	YEAR	TIME

EQUIPMENT

6. MODEL TYPE DESIGNATION

7. EQUIP. SERIAL NO.

8. CONTRACTOR (NAVY CODE OR COMPLETE NAME)

9. FIRST INDICATION OF TROUBLE (CHECK ONE)
1. INOPERATIVE
2. OUT OF TOLERANCE, LOW
3. OUT OF TOLERANCE, HIGH
4. INTERMITTENT OPERATION
5. UNSTABLE OPERATION
6. NOISE OR VIBRATION
7. OVERHEATING
8. VISUAL DEFECT
9. OTHER, EXPLAIN

10. OPERATIONAL CONDITION (CHECK ONE)
1. OUT OF SERVICE
2. OPERATING AT REDUCED CAPABILITY
3. UNAFFECTED

11. TIME METER READING
A. HIGH VOLTAGE
B. FILAMENT /ELAPSED

12. REPAIR TIME — MAN-HOURS — TENTHS

REPLACEMENT DATA

13. LOWEST DESIGNATED UNIT (U) or SUB-ASSEMBLY (SA)	14. LOWEST DES. U/SA SERIAL NO.	15. REFERENCE DESIGNATION (V-101, C-14, R11, ETC.)	16. FEDERAL STOCK NUMBER	17. MFR. OF REMOVED ITEM	18. TYPE OF FAILURE	19. PRIMARY OR SECOND-ARY FAIL?	20. CAUSE OF FAILURE	21. DISPOSITION OF REMOVED ITEM	22. REPL. AVAILABLE LOCALLY?
						P S			Y N
						P S			Y N
						P S			Y N
						P S			Y N
						P S			Y N

23. REPAIR TIME FACTORS

CODE	DAYS	HOURS	TENTHS	CODE	DAYS	HOURS	TENTHS

24. REMARKS (CONTINUE ON REVERSE SIDE IF NECESSARY)

84A-1

15.2

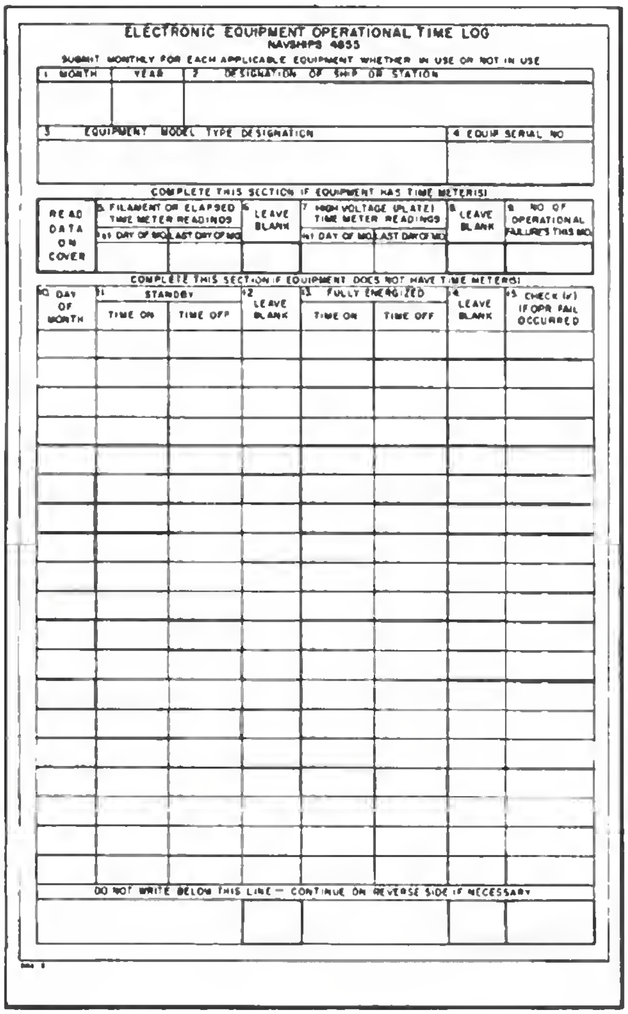
Figure 3-7.—Electronic equipment failure/replacement report.

Normally the electronics material officer will be responsible for making the necessary revisions to the record and submitting the reports. You will be required to furnish him the necessary information concerning the category 7 equipment.

OPERATING RECORDS AND REPORTS

Engineering operating records ensure frequent observation of operating machinery and equipment and also provide the basis for performance analysis. In addition to operating records, the engineer officer is responsible for preparing and submitting various reports which serve to keep BuShips and other activities informed on the day-to-day operations of the engineering department. These reports provide information on the status of material and equipment, and also provide data which afford a basis for design comparisons.

Most engineering operating records and reports will not concern you directly as an I.C. Electrician. As a senior petty officer in the engineering department however, you may be assigned department CPO duties in port. This will require you to be familiar with the various operating records maintained and have a general knowledge of the reports required by the department. In addition to the engineering department legal records (NavShips 116 & 117) and electrical log (NavShips 3649), discussed in I.C. Electrician 3, you should also become familiar with other operating records maintained in port. Among these are the Boiler Operating Record (NavShips 3651) and Refrigeration/Air Conditioning Equipment Operating Record (NavShips 4731). Other engineering department records you should become familiar with are the engineer officer's Night Order Book, Daily Fuel and Water Report to the Commanding Officer (NavShips 115), Steaming Orders, and department checkoff schedules for getting underway.



15.3

Figure 3-8.—Electronic equipment operational time log.

MISCELLANEOUS RECORDS

In addition to the I.C. records discussed in I.C. Electrician 3 and 2, and elsewhere in this chapter, you will be required to maintain rough workbooks and various other records. A partial list of these additional records and the sections of the BuShips Technical Manual in which they are discussed follows.

1. Circuit work sheets—65-44-3
2. Motor generator and controller work sheets—65-44-4
3. Switchboard work sheets—65-44-5
4. Trouble call sheets—65-44-6
5. Tests of grounded receptacles—60-26-3 (C)
6. Tests of portable electrical equipment—60-27-8(a)(b)(c)

ROUGH WORKBOOKS

Rough workbooks are normally ledger type notebooks maintained by petty officers in charge of a shop, space, circuit, or particular type equipment. They should contain rough notes on a day-by-day basis on all work accomplished. Material or repair parts used should be recorded along with sufficient details concerning repairs to support appropriate entries in the material history. These workbooks should be kept as neat as possible and up to date.

An effective policy on a large ship is to have a workbook for each circuit subgroup supervisor in the I.C. group. Weekly the senior or leading I.C. Electrician checks all workbooks to ensure that they are up to date and being maintained properly. He marks all items he considers significant enough to be entered on the electrical history cards. When the entry is made on the electrical history card the man making the entry initials and dates the item in the workbook.

NAVSHIPS 4110 (REV. 2-59)

SHIP ELECTRONICS INSTALLATION RECORD

DATE REVISED BY SHIP ____________

BUSHIPS REPORT 9670-2

SHIP TYPE	SHIP NUMBER	SHIP NAME	STATUS	AREA	FLT FRON	DIST COMM	BERTH AREA	PLAN. YARD	SHIP VOLT.	DATE MO	DATE DAY	DATE YR	DIST	OVHL. YARD
DD	999	Sampson	A	A	50	94		NF	D					

S C C CODE FOR BUREAU USE ONLY	CAT	LOCATION	EQUIPMENT MODEL	SERIAL NUMBER	EQUIPT VOLTAGE 1	EQUIPT VOLTAGE 2	REMARKS
	7	211	AN/SIQ-3	M124791		8	
	7	330	LS/380-SIC	M2961A		X	
	7	340	AN/SIA-11	H1134		8	
	7	800	LS/285/SIC	NH100		X	
	7	820	LS/329/SIC	NC-264-4		8	
	7	900	AN/SIH-1	IC/RPM-4K		8	
	7	900	RD-152/SNH	246890		8	
	7	900	PP-1390/U	43503		8	
	7	910	AM-1360/U	MI-2818-B		8	

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Figure 3-9.—Sample electronics installation record—category 7 equipment.

CHAPTER 4

MAGNETIC AMPLIFIER APPLICATIONS

Magnetic amplifiers are widely used aboard ship as regulators to control the voltage, current, and frequency of the main propulsion plant and of auxiliary units. Also they will be used extensively in the future as a complete replacement for the thyratron and amplidyne controls in servosystems aboard ship. Speed-regulation equipment that utilizes magnetic amplifiers is also installed aboard ship to provide a closely regulated 400-cycle power supply for certain interior communications and fire control equipment. In this chapter only voltage and speed-regulator units will be discussed.

An application of magnetic amplifiers is found in a special type of motor-generator power supply for certain interior communications and fire control equipments. Most ships have two of these motor-generator sets. Usually the generators can be operated in parallel.

The sets provide a closely regulated 3Φ, 120 volt, 400-cycle output. Speed regulation is obtained by means of a magnetic-particle clutch between the motor and generator. Accessory control equipment functions to start the motor and to regulate the voltage and frequency of the a-c generator. Magnetic amplifiers are used in the voltage regulator and also in the speed regulator. A diagram of the closely regulated system is indicated in figure 4-1.

MOTOR-CLUTCH GENERATOR

The motor-clutch generator consists of an induction motor and an a-c generator that are mounted on a common bedplate. The shafts of the motor and generator are coupled by means of a magnetic-particle clutch.

MOTOR

The motor is a 15-hp, 3-phase, 440-volt, 60-cycle induction motor that has a full-load speed of 3530 rpm at rated frequency. The speed of this motor changes with the load and the frequency of the power supply, and at no load the speed is 3550 rpm.

GENERATOR

The generator is a 5-kw, 3-phase, 120-volt, 400-cycle synchronous generator that has a speed of 3428 rpm. The rotor speed of this generator must be maintained at this value to provide a 400-cycle output.

MAGNETIC-PARTICLE CLUTCH

The magnetic-particle clutch (fig. 4-2) is the controllable coupling that transmits mechanical power from the motor to the generator. The difference between the changing motor speed and the required constant generator speed for 400 cycles is absorbed as controlled slip in the magnetic clutch.

The magnetic-particle clutch consists essentially of two independent rotating members; (1) the inner-driving member which is connected to the motor shaft and (2) the outer-driven member which is connected to the generator shaft through a flexible coupling. The working gap between these two members is partially filled with a mixture of iron particles and graphite.

The power is fed to the control coil through slip rings (not shown), and the resulting flux path is indicated by the broken line. The magnetic circuit includes the two halves of the inner member, the driven ring of the outer member, and the working gap, which contains the magnetic mixture.

The magnetic field, produced between the field yokes by the current in the control coil, forms chains of iron particles that adhere to the two clutch members. The number and stiffness of these chains are determined by the strength of the magnetic field. The stronger the field the more nearly solid becomes the mixture.

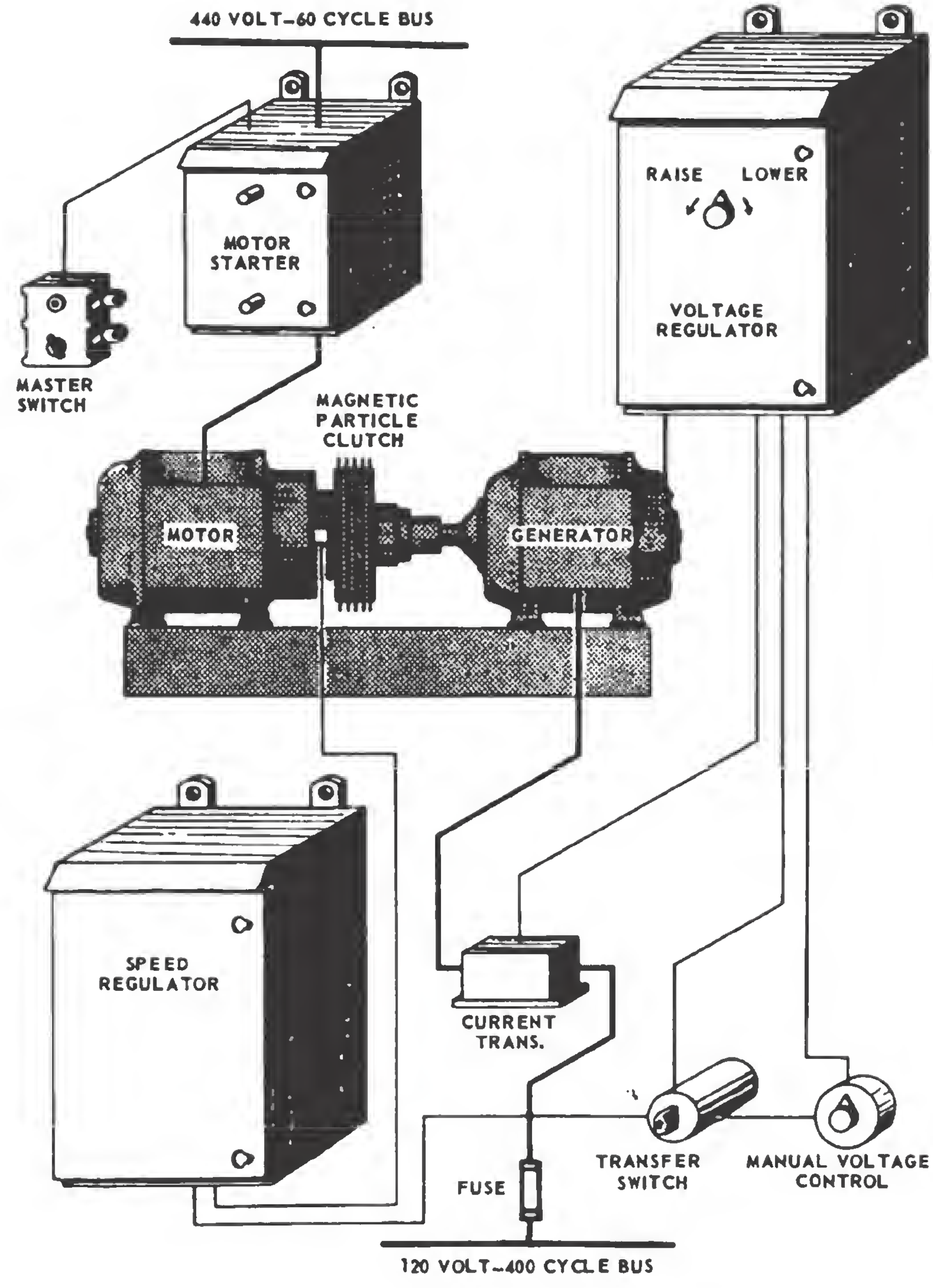

Figure 4-1.—Closely regulated system diagram.

The magnetic-particle clutch functions to control the difference between the motor and generator speeds. This speed difference appears as slip in the clutch. The slip and the speed of the outer-driven member can be regulated by varying the current in the control coil. The speed regulator, included in the accessory control equipment, automatically adjusts this clutch-coil current to control the output frequency of the a-c generator, which is coupled to the outer-driven member.

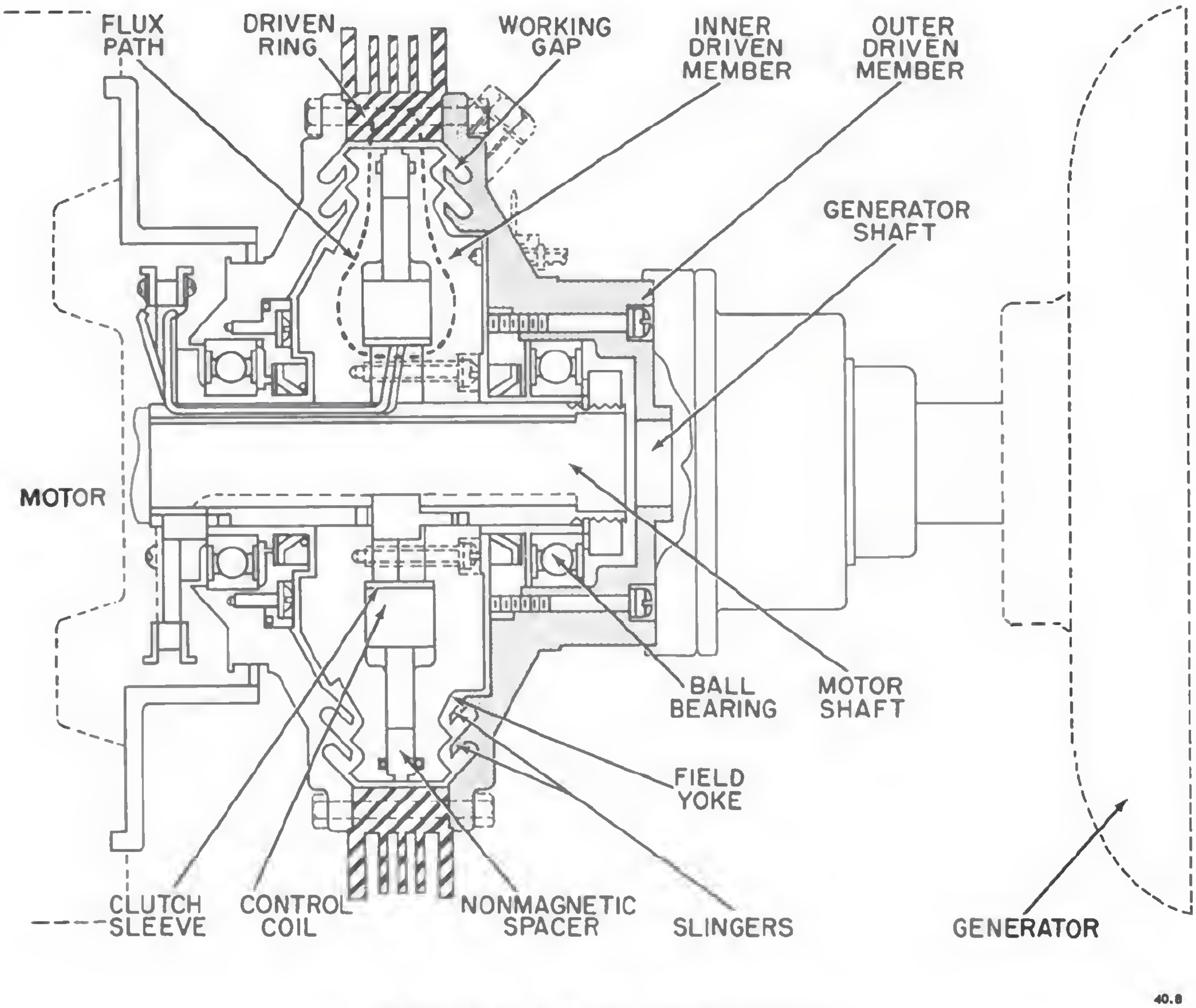

Figure 4-2.—Magnetic-particle clutch.

ACCESSORY CONTROL EQUIPMENT

The accessory control equipment includes (1) a motor controller, (2) a master switch, (3) an automatic-manual transfer switch, (4) a speed regulator, and (5) a voltage regulator. When two complete speed-regulation systems are equipped for parallel operation (fig. 4-3), a parallel-operation relay and an automatic load-division assembly are included with the accessory control equipment.

The motor controller (fig. 4-3) includes a magnetically operated contactor, overload relays, and a pilot-circuit fuse. These components are mounted on a removable panel that is enclosed within a dripproof case provided for bulkhead mounting. The speed-regulation system is operated by closing the master switch in the pilot circuit to energize the operating coil of the line contactor.

The master switch (fig. 4-3) consists of two independent switches enclosed within a moisture-proof case provided for mounting on the switchboard. One switch marked STOP and START is a two-position rotary-type switch. The other switch, marked EMERGENCY, is a normally open, single-spring return type of push switch that permits operation of the controller independently of the overload protection.

The automatic-manual transfer switch (not shown) is an enclosed rotary switch mounted on the back of the switchboard with the operating

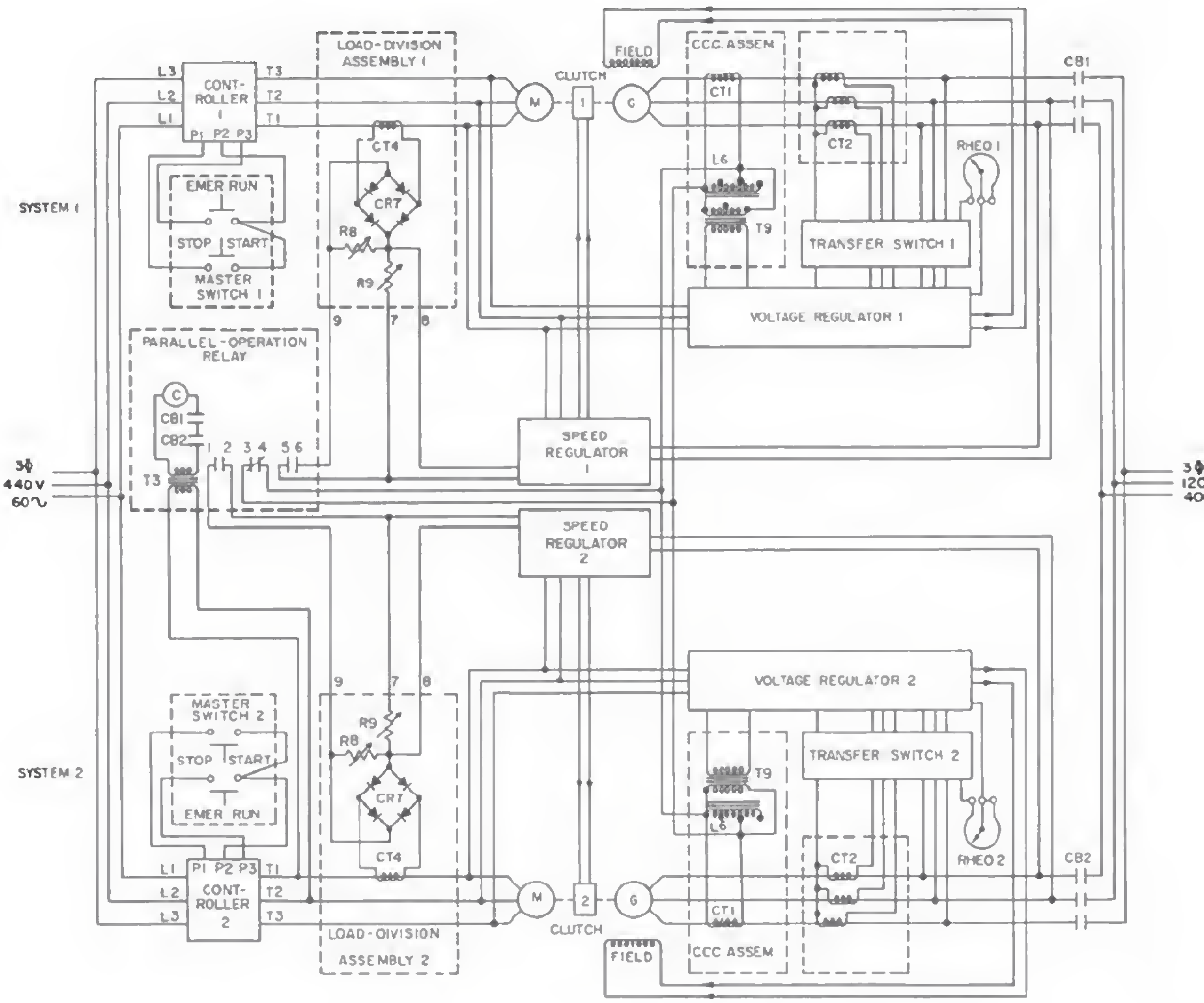

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Figure 4-3.—Parallel operation of two speed-regulation systems.

handle projecting through the switchboard panel. It has four positions that function to interconnect the various voltage-regulator components that are necessary for the desired operation of the system. The OFF position deenergizes the voltage regulator; the START position energizes the control coil of the magnetic-particle clutch so that the generator attains speed; the MANUAL position provides manual control of the generator voltage; and the AUTOMATIC position provides complete automatic operation of the system.

SPEED REGULATOR

The speed regulator (fig. 4-4) controls the slip of magnetic-particle clutch (under all load conditions) to regulate the frequency of the a-c generator output. It consists of a (1) starting circuit, (2) resonant-detector circuit, (3) preamplifier circuit, and (4) power-amplifier circuit. The preamplifier and power amplifier are magnetic amplifiers that employ high permeability cores.

Starting Circuit

The starting circuit (fig. 4-5) provides the initial excitation for the speed regulator. When the remotely located master switch is in the START position, the motor controller connects the a-c induction motor of the motor-clutch generator across the 3-phase, 440-volt, 60-cycle

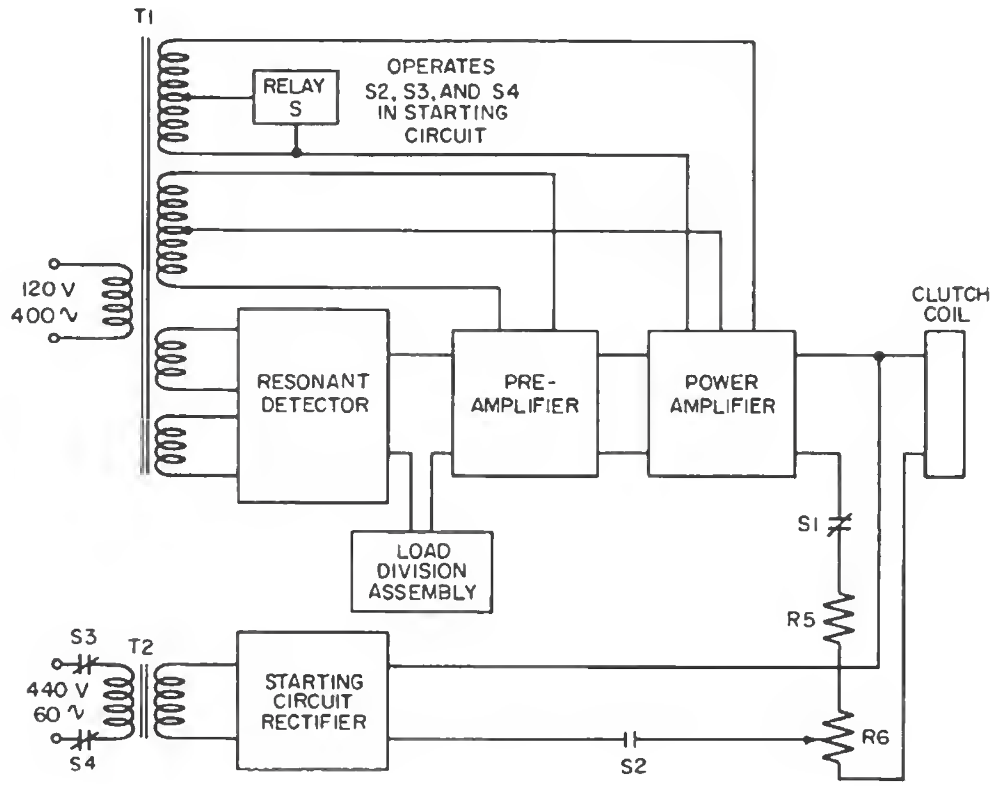

Figure 4-4.—Speed regulator, block diagram.

line (fig. 4-3). However upon starting the power supply, the a-c generator does not rotate, except possibly at a relatively low speed, because no excitation is immediately available to the magnetic-particle clutch due to the self-inductance of the control coil circuit. The single-phase, 440-volt, 60-cycle supply that is impressed across the speed regulator is applied to transformer T2 through normally closed relay contacts S3 and S4 because relay S in the speed regulator is deenergized. Rectifier CR5, through normally closed relay contact S2, supplies direct current to the control coil in the magnetic-particle clutch. When the control current builds up sufficiently, the a-c generator connected to the output shaft of the magnetic-particle clutch will rotate at motor speed because the d-c voltage applied to the clutch coil is of the proper magnitude to lock in the clutch.

When the automatic-manual transfer switch (not shown) is in the START position, excitation is supplied by the voltage regulator to the a-c generator field; a single-phase, 400-cycle voltage is impressed across the speed regulator through the primary of the main power transformer, T1, in the speed regulator. As the value of the impressed voltage approaches 120 volts, the speed-regulator circuits, supplied by the secondaries of transformer T1, are energized. Relay S operates to close contact S1 and to open the normally closed contacts, S2, S3, and S4 (fig. 4-3). This action disconnects the 60-cycle excitation supply from the starting circuit in the speed regulator, and it supplies current to the magnetic-particle clutch from rectifier CR5 thrugh the speed regulator.

Resonant Detector Circuit

The resonant detector circuit consists of the full-wave bridge rectifiers, CR1 and CR2, supplied from transformer T1 through separate series resonant circuits that consist of C1-L1 and C2-L2, respectively.

The purpose of the L-C networks is to automatically maintain the output of the 400-cycle m-g set at approximately a 400∿ frequency

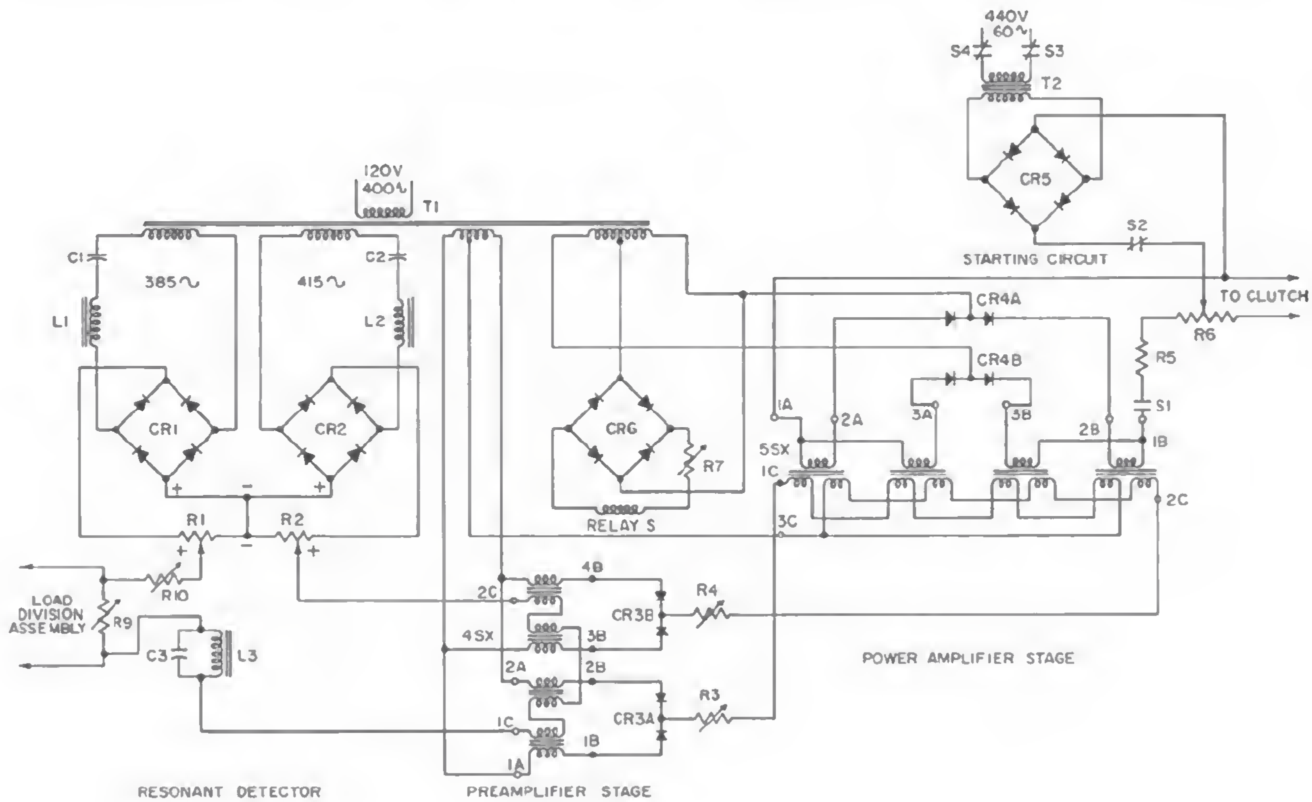

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Figure 4-5.—Speed regulator starting circuit.

(385 to 415~). This action is accomplished by the two L-C networks, establishing low and high limits on any variation of the 400~ output that might occur, as follows.

The series resonant circuit, C1-L1, is in series with a secondary of transformer T1 through rectifier CR1. When the frequency of the a-c generator output voltage applied to the speed regulator is approximately 385 cycles, the impedance of this resonant circuit is nearly zero; that is, C1 and L1 are in series resonance, and most of the voltage supplied by the secondary of T1 is applied to rectifier CR1 and potentiometer R1. Thus, the direct current from CR1 is relatively high, and the voltage across potentiometer R1 is also high. If the frequency of the applied voltage to the speed regulator deviates from 385 cycles, the impedance of this resonant circuit increases very rapidly, and most of the voltage supplied by the secondary of T1 is dropped across this impedance. This action reduces the voltage supplied to CR1 and R1, thereby reducing the d-c output voltage.

The resonant circuit consisting of C2 and L2 is in series with a secondary of transformer T1 through rectifier CR2. When the frequency of the a-c generator output voltage that is applied to the speed regulator is approximately 415 cycles, the impedance of this resonant circuit is nearly zero; that is, C2 and L2 are in series resonance, and most of the voltage supplied by the secondary of T1 is applied to rectifier CR2 and resistor R2. Thus, the direct current from CR2 is relatively high, and the voltage across potentiometer R2 is also high. If the frequency of the applied voltage deviates from 415 cycles, the impedance of this resonant circuit increases very rapidly, and most of the voltage supplied by the secondary of T1 is dropped across this impedance. This action reduces the voltage supplied to CR2 and R2, thereby reducing the d-c output voltage.

The resultant d-c output voltage of CR1 and CR2 across potentiometers R1 and R2 is fed to the control winding, 1C-2C, of reactor 4SX in the preamplifier stage of the regulator through an 800-cycle second-harmonic wavetrap that is comprised of capacitor C3 and inductor L3.

These units are parallel resonant at 800 cycles and so remove any 800-cycle frequency component from the output to the preamplifier stage by presenting a high series impedance at this frequency.

The output of the resonant detector circuit, fed to the preamplifier stage, is a reversible direct current determined by the frequency of the a-c generator output voltage applied to the regulator. If the frequency of the applied voltage is near 385 cycles, more current flows in R1 than in R2, and terminal 1C will be positive with respect to terminal 2C. Conversely, if the frequency of the applied voltage is near 415 cycles, more current flows in R2 than in R1, and the polarity of the output signal, fed to the preamplifier stage, is reversed.

Thus, the resonant detector circuit changes frequency variations of the applied input voltage into polarity variations of the output voltage, which are fed to the preamplifier stage. Polarity depends on frequency, and when the frequency of the applied input voltage is 400 cycles, both halves of the resonant detector circuit are balanced, and the value of the resultant output voltage is practically zero.

When the frequency of the voltage that is applied to the speed regulator is less than 400 cycles, the impedance of the resonant circuit, comprising C1 and L1, decreases as the value of the generator output deviates above its series resonance of 385 cycles. This action allows more current to flow from the secondary of T1 through CR1 and R1. Simultaneously, the impedance of the resonant circuit, comprising C2 and L2, increases as the value of the generator output deviates below its series resonance of 415 cycles. This action reduces the flow of current from the secondary winding of T1 through CR2 and R2, making terminal 1C more positive with respect to terminal 2C.

Preamplifier Circuit

The preamplifier circuit (fig. 4-5), the principal component of which is the saturable reactor, 4SX, has two output circuits. Each output circuit comprises two load windings. One output circuit supplies rectifier CR3A through load winding terminals 1B and 2B. The other output circuit supplies rectifier CR3B through load winding terminals 3B and 4B. The signal from the resonant detector circuit is fed to terminals 1C and 2C of the control windings.

The control windings are so wound on the cores that they produce opposite effects on the two output circuits. When terminal 1C of 4SX is positive with respect to terminal 2C, the cores of load windings 1A-1B and 2A-2B become saturated. The impedance of these windings decreases and most of the voltage from the secondary of T1 is available for the load. This action results in an increase in current to CR3A and R3. Simultaneously, the cores of load windings 1A-3B and 2A-4B become desaturated. The impedance of the windings increases, and most of the voltage applied to terminals 1A and 2A of 4SX from the secondary of T1 is dropped across these load windings. Hence, little of the supply voltage is available for the load. This action results in a decrease in current to CR3B and R4.

Conversely, when terminal 2C is positive with respect to terminal 1C, the reverse action occurs and more current flows in R4 than in R3. When the potential between terminals 1C and 2C is zero, which occurs when the frequency of the generator output is 400 cycles, equal currents flow in resistors R3 and R4.

Therefore, reactor 4SX converts voltage-polarity changes into current variations in the output of the preamplifier stage. This d-c output current is fed from terminals 1C and 2C to the separate control windings, 1C-3C and 2C-3C, of the reactor, 5SX, in the power amplifier stage.

Power Amplifier Circuit

The power amplifier circuit (fig. 4-5) has as its principal component, saturable reactor 5SX. The output of 5SX is fed to the control coil of the magnetic-particle clutch through reactor terminals 1A and 1B of the power amplifier stage.

The signal current from the preamplifier stage is fed to terminals 1C and 2C of reactor 5SX. The two control windings 1C-3C and 2C-3C of 5SX are wound on the cores so that they produce opposite effects on the load windings. The current in control winding 1C-3C tends to saturate reactor 5SX, whereas the current in control winding 2C-3C tends to desaturate reactor 5SX. The net effect of the two control windings provides the control current for 5SX, the output of which controls the amount of current supplied to the magnetic-particle clutch. When the magnitude of the d-c signal in control winding 1C-3C is greater than that of the d-c signal in control winding 2C-3C, reactor 5SX becomes

saturated and its impedance decreases. Thus, most of the voltage supplied to 5SX by the secondary winding of T1 is available for the load which is the control coil of the magnetic-particle clutch.

Conversely, when the magnitude of the d-c signal in the control winding, 2C-3C, is greater than that of the d-c signal in the control winding, 1C-3C, reactor 5SX becomes desaturated and its impedance increases. Thus, most of the voltage supplied to 5SX by the secondary winding of T1 is dropped across the load windings of 5SX, and little voltage is available for the control coil of the magnetic-particle clutch.

When a decrease in the frequency of the input voltage occurs across the primary of transformer T1 in the speed regulator, the resonant detector circuit feeds a signal to the preamplifier stage, which supplies more current to control winding 1C-3C than is supplied to control winding 2C-3C of the power amplifier stage, 5SX. This action tends to saturate 5SX, thereby permitting an increase in current to flow through reactor load winding terminals 1A and 1B to the control coil of the magnetic-particle clutch. This increase in current to the control coil reduces the slip of the magnetic-particle clutch and the generator speeds up, thereby increasing the frequency of the generator output. When the generator speed returns to normal, the speed-regulator circuits automatically readjust to produce the reverse action until the frequency is stabilized at 400 cycles.

PARALLEL OPERATION RELAY

The parallel-operation relay (fig. 4-3) consists of a relay and transformer T3 that are enclosed within a drip-proof case provided for bulkhead mounting. The relay is of the magnetic spring-loaded type with two normally open and one normally closed contacts. When both generator breakers are closed, the relay is energized through transformer T3 from the 440-volt, 60-cycle bus through auxiliary contacts CB1 and CB2 on each generator circuit breaker. The transformer supplies 115 volts to the relay.

This action interconnects the load division assemblies through relay contacts 1-2 and 5-6. At the same time relay contacts 3-4 open the short circuit across the cross-current compensation assemblies and proper control of excitation is assumed. If either of the speed regulation systems is shut down, the parallel-operation relay is automatically disconnected by the circuit-breaker auxiliary contacts, CB1 or CB2, to disconnect the parallel-operation components.

AUTOMATIC LOAD-DIVISION ASSEMBLY

The function of the load division assembly is to maintain equal load on each 400-cycle power supply system for parallel operation of two systems. The automatic load-division assembly (fig. 4-3) consists of resistors R8 and R9, full-wave rectifier CR7, and current transformer CT4. Transformer CT4 is inserted in series with one phase of the 3-phase, 440-volt, 60-cycle input to the a-c motor. These components are enclosed within a drip-proof case mounted on the a-c motor frame.

Current transformer CT4 of the load-division assembly (fig. 4-6) supplies a voltage proportional to the motor current to rectifier CR7. The d-c output signal of CR7 is fed to resistors R8, one being located in each load-division assembly. These two d-c signals are connected in opposition through terminals 7 and 9 in each load-division assembly and the relay contacts in the parallel-operation relay. When the two motor currents are equal, the opposing d-c

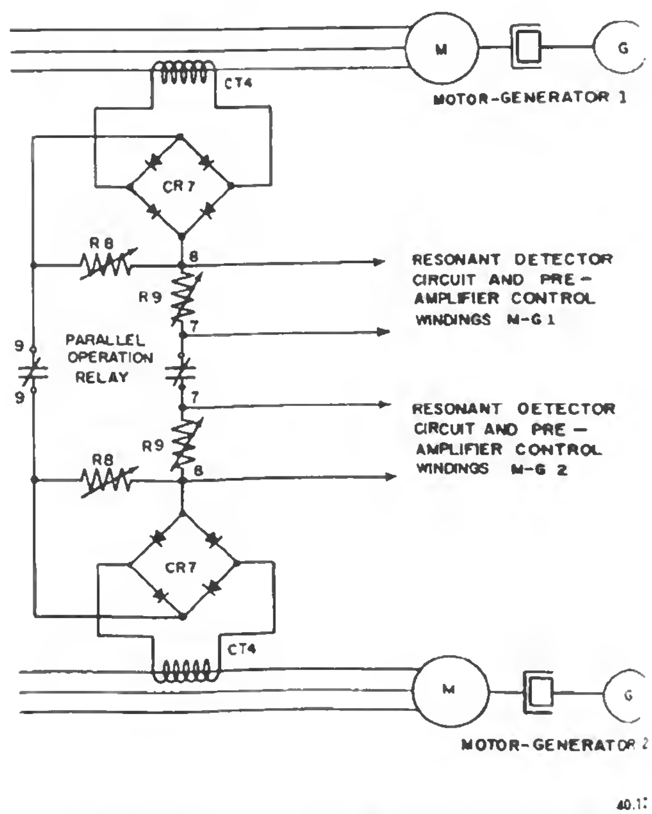

Figure 4-6.—Load division assemblies.

voltages cancel each other; no effect is produced. On the other hand, when one generator tends to carry more than half the load, a circulating current flows through resistors R9, one being located in each load-division assembly. This action results in a voltage drop across resistors R9, which is inserted between terminals 7 and 8 in each load-division assembly. This voltage is of reversible polarity. It always makes terminal 8 positive with respect to terminal 7 on the more heavily loaded generator and vice versa on the more lightly loaded generator.

The output of the resonant detector circuit (fig. 4-5) must flow through resistor R9 in the load-division assembly before it is fed to the control winding of reactor 4SX in the preamplifier stage. Hence, resistor R9 is common to both the resonant detector circuit and the load-division assembly and there are two voltages of reversible polarity in series supplying the control windings, 1C-2C, of reactor 4SX (fig. 4-6). One voltage, derived from a resonant detector circuit through resistors R1 and R2, develops from a change in the frequency of the input voltage applied to the speed regulator (fig. 4-3). The other voltage, derived from resistor R9 in the load-division assembly, develops from the unequal load division between the generators and is applied to the speed regulators. A change in either of these voltages has the same effect on the preamplifier-stage output and acts to change the value of the voltage supplied to the control coil of the magnetic-particle clutch. Hence, the signal fed to the speed regulators results in decreased clutch excitation to the system with the higher motor current and increased clutch excitation to the system with the lower motor current.

Under single system operation the load-division circuit is not connected into the regulating system and the secondaries of the current transformers supplying the cross-current compensation assemblies are shorted by contacts 3-4 of the parallel operation relay (fig. 4-3).

VOLTAGE REGULATOR

The voltage regulator supplies the d-c excitation for the generator field. The block diagram (fig. 4-7) includes the voltage regulator. It consists essentially of three components; (1) voltage detector, (2) preamplifier, and (3) power amplifier. The detector is sensitive to generator voltage changes and supplies a signal proportional to these generator voltage changes to the preamplifier. The signal is amplified and supplied to the power amplifier. The power amplifier controls the excitation current to the generator field. Provisions are made for manual and automatic control of the voltage regulator. Current transformers CT2 provide additional excitation that is proportional to the load current.

As mentioned before, the starting circuit (fig. 4-8) provides the initial field excitation for the generator. When the remotely located master switch is operated to its START position, the motor controller functions to connect the a-c induction motor of the motor-clutch generator across the 3-phase, 440-volt, 60-cycle source (fig. 4-3). The a-c generator output voltage does not build up at this time because no excitation is available to the generator field.

When the automatic-manual transfer switch (not shown) is operated to its START position, the primaries of transformer T5 (fig. 4-8) within the voltage regulator are connected to the 3-phase, 440-volt, 60-cycle bus. The wye-connected secondaries of transformer T5 energize rectifiers CR1A, CR1B, and CR1C in the power amplifier stage of the voltage regulator through switch contacts S10, S11, and S12. The impedance of reactor 1SX at 60 cycles is sufficiently low to pass no-load direct current to the a-c generator field through reactor terminals 1A and 1B; the a-c generator output voltage builds up. The bias and control windings of 1SX are not used during the period of initial excitation.

The manual-voltage control circuit (fig. 4-9) provides manual control of the a-c generator output voltage over a relatively wide range by means of the manual voltage control rheostat, Rheo. 1. This circuit is intended for emergency use only.

When the automatic-manual transfer switch (not shown) is in the MANUAL position, the manual-voltage-control rheostat, Rheo. 1, mounted on the switchboard, is connected into the voltage-regulator circuit.

The generator field now derives its power from its own armature. The path includes the wye-connected secondaries of transformer T6; the load windings of power amplifier 1SX; rectifiers CR1A, CR1B, and CR1C; inductors L2A, L2B, and L2C; and switch contacts 7, 8, and 9. Under conditions of manual control, power for the control winding, 1C-2C, of the power amplifier, 1SX, is obtained from the delta-connected

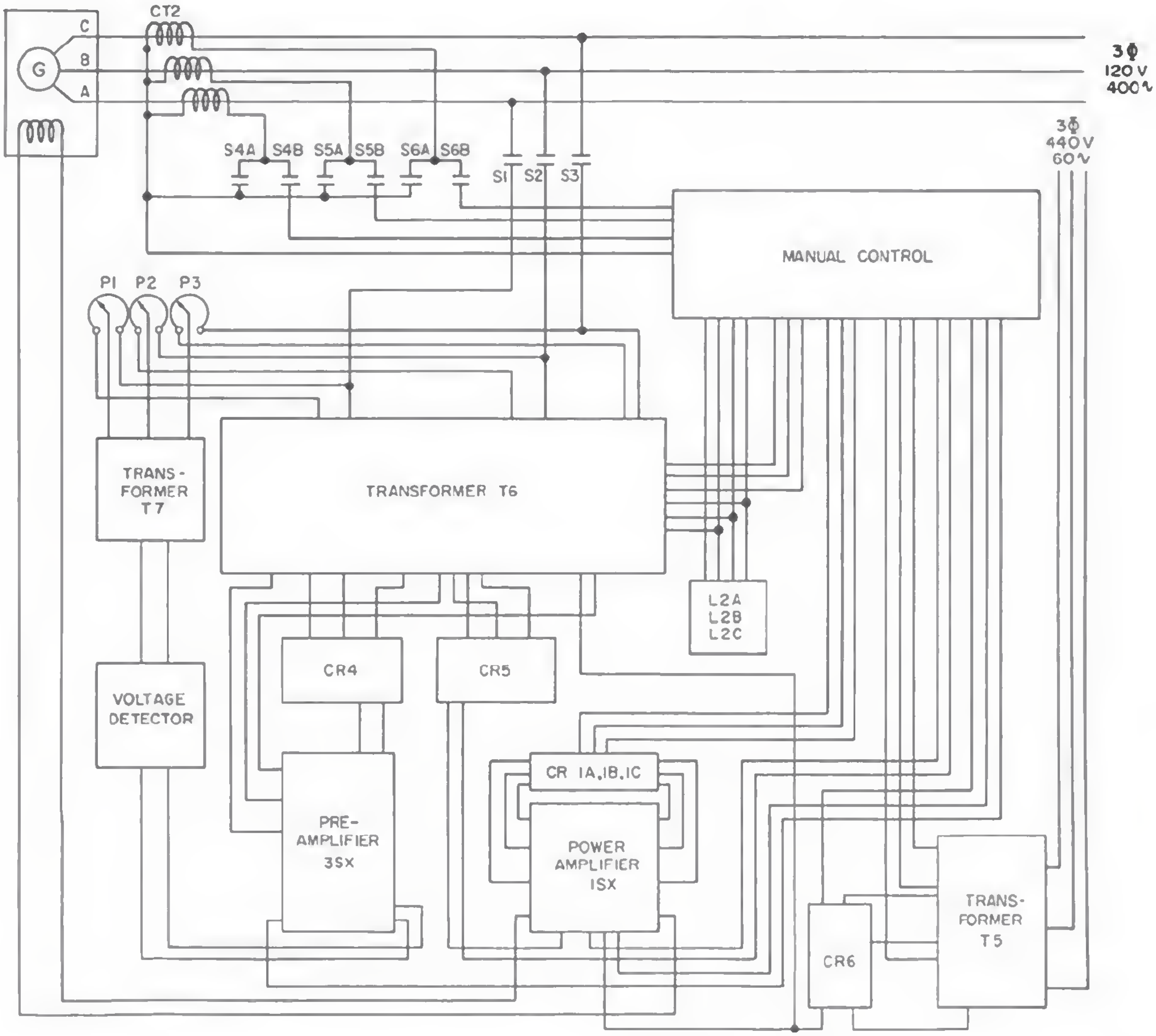

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Figure 4-7.—Block diagram of voltage regulator.

secondaries of transformer T5, which is energized from the 440-volt, 60-cycle bus. The current for the control windings, 1C-2C, of the power amplifier, 1SX, is regulated by the manual-voltage-control rheostat, Rheo. 1, and is in a direction that tends to saturate the core of power amplifier 1SX (opposite to that under automatic control). For example, increasing the amount of control current to winding 1C-2C will saturate 1SX, thereby causing a decrease in the impedance of the six load windings and making available for the generator field most of the rectified supply voltage from transformer T6. This d-c output voltage is supplied to the generator field through power amplifier terminals 1A and 1B, thereby increasing the field current and generator output voltage.

Conversely, a decrease in the current in control winding 1C-2C desaturates reactor 1SX, causing a corresponding increase in the impedance of the load windings. Thus, most of the supply voltage is expended across the reactance

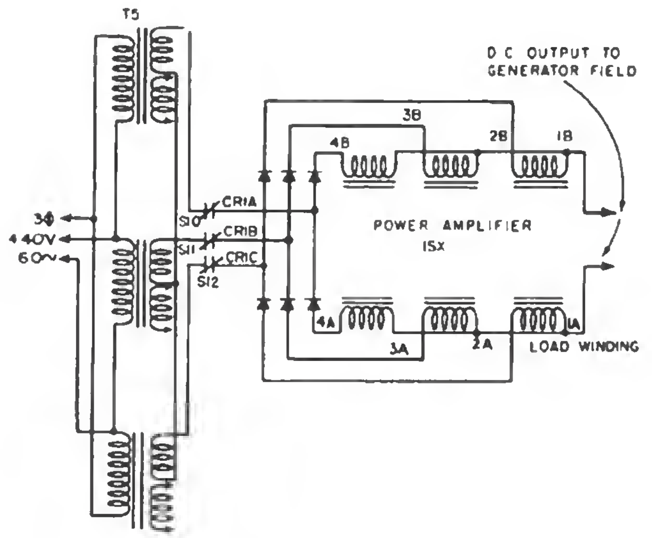

Figure 4-8.—Voltage-regulator starting circuit.

of the load windings of 1SX, resulting in a decrease in the generator output voltage. The bias winding of amplifier 1SX is not used under manual-control conditions.

When the transfer switch (fig. 4-3) is in the automatic position, the voltage regulator automatically regulates the generator output voltage. Automatic control utilizes the voltage detector, preamplifier, and power amplifier, as illustrated in the schematic circuits of figure 4-10.

Voltage Detector

The voltage detector circuit (fig. 4-10) consists of a full-wave bridge rectifier CR3, supplied from the delta-connected secondaries of transformer T7. Rectifier CR3 is inserted within the closed loop formed by the delta-connected secondaries of T7. The fundamental frequency components of the secondary voltage are canceled within the loop, but the third harmonic voltages of each generator phase are additive and are rectified to produce a single d-c control current. When transformer T7 is operated at the proper flux value, its sensitivity is high, the rectified current versus input voltage is very steep, and the output current changes many times as rapidly as the input voltage.

Transformer T7 is supplied from potentiometers P1, P2, and P3. Each potentiometer is connected across a portion of the primary windings of T6. The adjustable contacts are activated by a common control shaft and thus provide simultaneous and equal adjustment of the three sections of the potentiometers. The adjustment of P1, P2, and P3 controls the relationship between the a-c generator bus voltage, which energizes T6 and the detector voltage, which is derived from the output of T7. For example, when P1, P2, and P3 are adjusted so that the voltage to T7 is increased, the d-c control current, derived from the voltage-detector circuit across CR3, increases rapidly. The voltage regulator acts as if the bus voltage were high and automatically reduces the excitation supplied to the generator field. The bus voltage will then drop. Conversely when P1, P2, and P3 are adjusted so that a smaller portion of the generator output is applied to the detector, the regulator acts as if the bus voltage were low, the excitation supplied to the generator field is increased, and the bus voltage will rise.

Hence, the regulated-voltage control potentiometers, P1, P2, and P3, control the portion of the voltage that is applied to the voltage regulator and may therefore be used to set the level at which the generator output voltage is regulated.

The voltage-detector circuit functions to detect changes in the supply voltage applied to transformer T6 and to transmit these changes in the form of a d-c signal to the voltage-regulator preamplifier stage. When the input voltage to T6 is high, the voltage-detector output is high; when the input voltage to T6 is low, the voltage-detector output is low. The d-c output of the voltage-detector circuit is fed to the control windings, 1C-2C, of the preamplifier stage, 3SX.

Preamplifier

The preamplifier circuit (fig. 4-10) consists essentially of the magnetic amplifier reactor, 3SX, with bias winding 1B-2B and control winding 1C-2C, connected in opposition. The bias current in winding 1B-2B tends to desaturate the core of 3SX, whereas the control current in winding 1C-2C is in the saturating direction. Hence, the output of 3SX is directly proportional to the control current derived from the voltage-detector circuit.

The preamplifier stage of the voltage regulator amplifies the d-c signal from the detector and applies this amplified signal in the form of a direct current to the regulator power amplifier

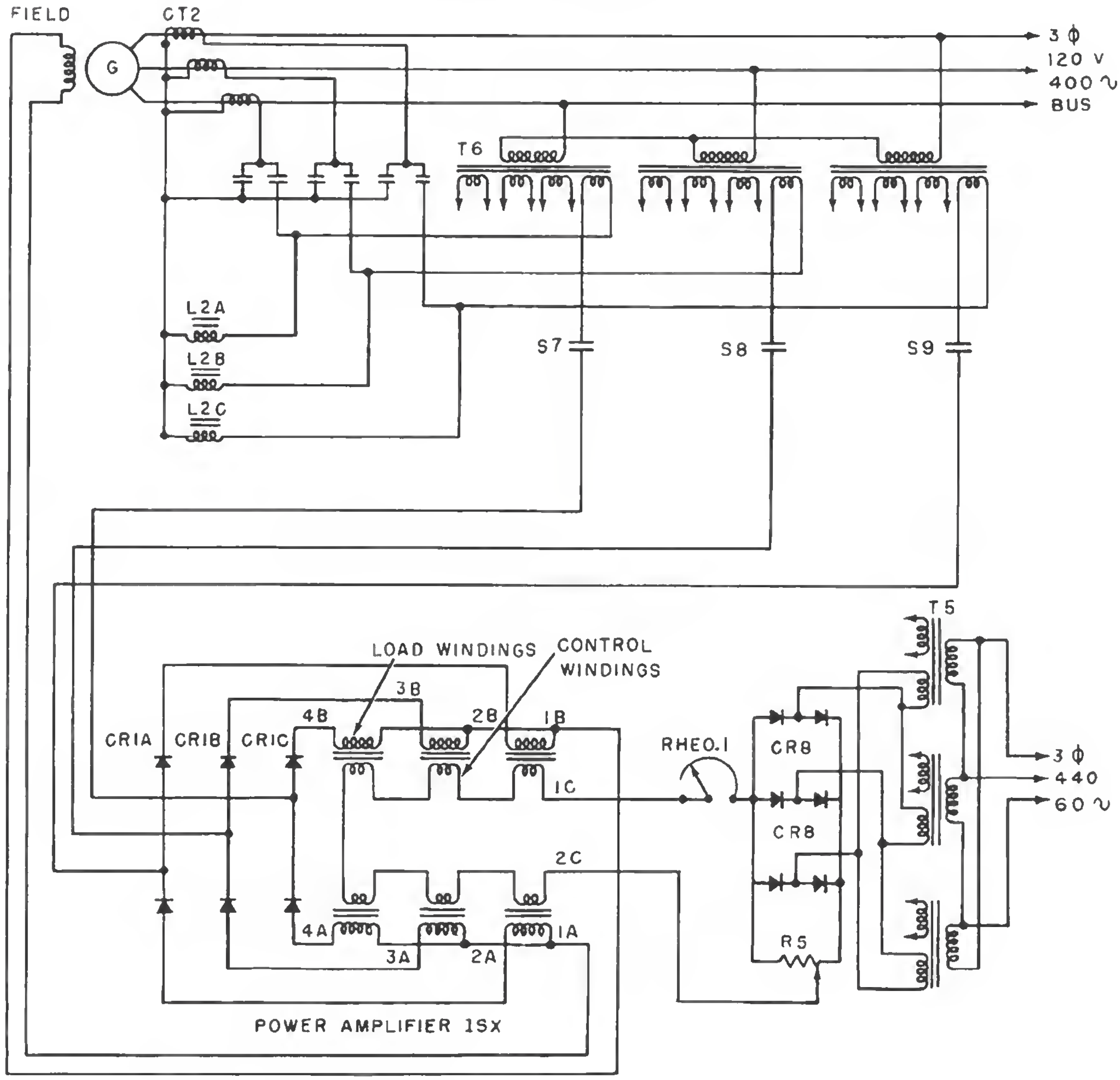

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Figure 4-9.—Voltage-regulator manual-voltage control circuit.

stage. When the detector signal that is applied to the control winding of 3SX is small because of low bus voltage, the bias mmf desaturates the core of 3SX and thus increases the impedance of the load windings. Hence, a large portion of the voltage from T6 supplies through rectifiers CR2A, CR2B, and CR2C is expended as voltage drop across the load windings of 3SX, and little voltage is available for the load.

On the other hand, when the detector signal applied to the control winding is large because of high bus voltage, the control mmf counteracts the bias mmf, and the core of 3SX becomes saturated, thereby decreasing the impedance of the load windings. Hence, most of the voltage from transformer T6 that is supplied through rectifiers CR2A, B, and C is available for the load. The d-c output of the preamplifier stage

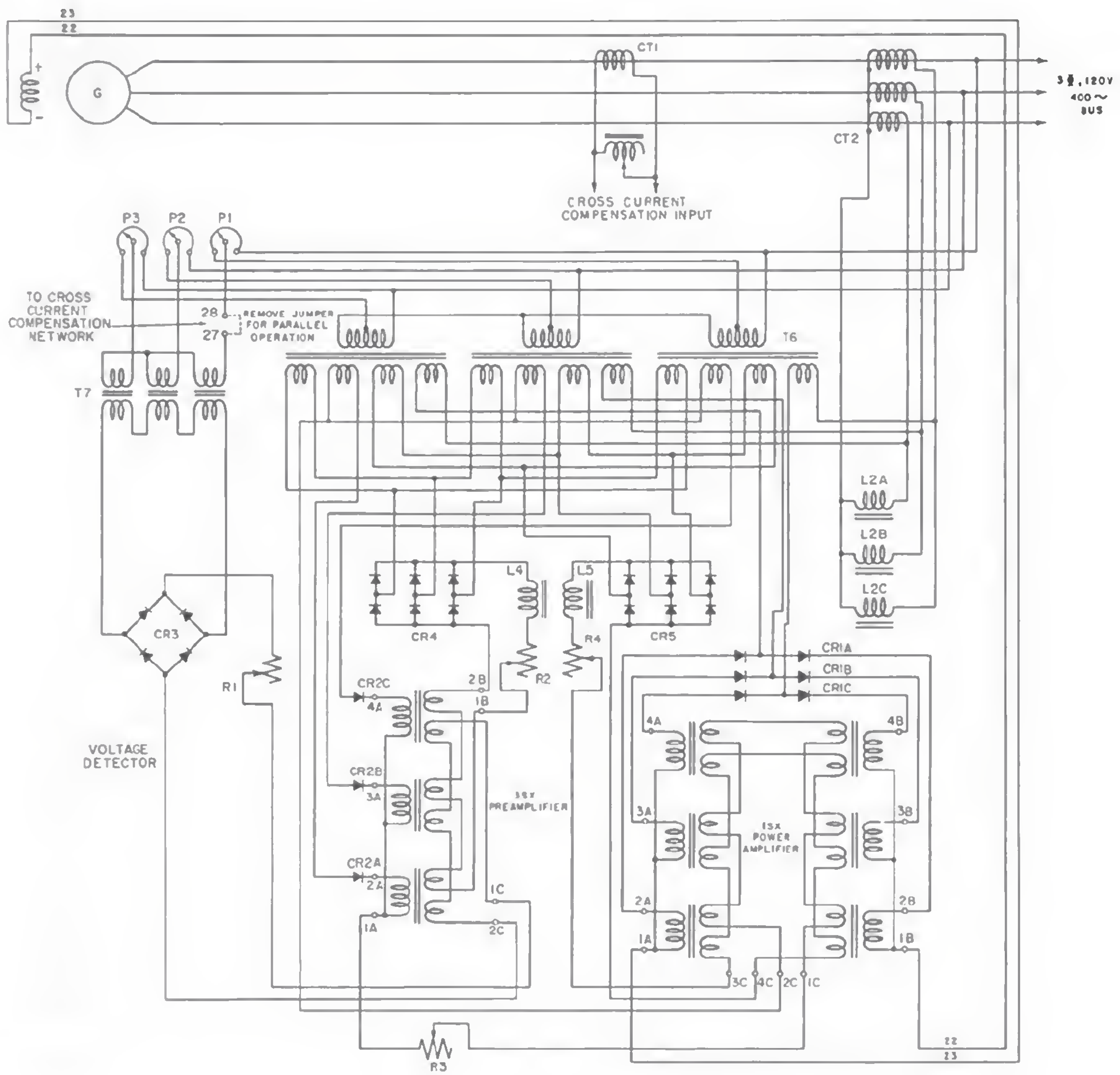

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Figure 4-10.—Voltage-regulator automatic-control schematic circuit.

is fed to the control winding, 1C-2C, of the power amplifier, 1SX, of the voltage regulator.

Power Amplifier

The POWER AMPLIFIER CIRCUIT (fig. 4-10) consists principally of saturable reactor 1SX with bias winding 3C-4C and control winding 1C-2C connected in opposition. The bias current in winding 3C-4C tends to saturate 1SX, whereas the control current in winding 1C-2C is in the desaturating direction. Hence, the output of 1SX is inversely proportional to the control current derived from the preamplifier stage.

The power amplifier stage of the voltage regulator controls the generator-field current. When the preamplifier signal that is applied to

the control winding is low because of low bus voltage applied to the speed regulator, the bias flux saturates the core of 1SX, and thus decreases the impedance. Hence, most of the voltage supplied to 1SX from transformer T6 and inductors L2A, L2B, and L2C is available for the load.

On the other hand, when the preamplifier signal, applied to the control winding, is high because of high bus voltage applied to the speed regulator, the control flux counteracts the bias flux and desaturates the core of 1SX, thereby increasing the impedance. Hence, most of the voltage to 1SX from transformer T6 and inductors L2A, L2B, and L2C is expended as voltage drop across reactor 1SX, and little voltage is available for the generator field, which is connected to terminals 1A and 1B of reactor 1SX.

Figure 4-10 illustrates that portion of the voltage-regulator automatic-control circuit that has been discussed thus far; that is, the voltage-detector circuit, the preamplifier stage, and the power-amplifier stage. The signal amplification that would be caused in this combined circuit by a decrease in the bus voltage is as follows: (1) the control current input from the preamplifier stage to control winding 1C-2C of power amplifier 1SX decreases; (2) the core flux of 1SX increases because the saturating-bias mmf is opposed by less desaturating-control mmf; (3) the impedance of the load windings of 1SX decreases, and the direct current output to the generator field increases. This action increases the generated voltage, thereby checking the decrease in terminal voltage.

Conversely, if the generator output voltage increases, the following action will occur; (1) the control-current input from the preamplifier stage to control winding 1C-2C of power amplifier 1SX increases; (2) the core flux of 1SX decreases because the saturating-bias mmf is opposed by more desaturating-control mmf; (3) the impedance of the load windings of 1SX increases, and the direct current output to the generator field decreases. This action decreases the generated voltage, thereby checking the increase in terminal voltage.

Current transformers CT2 function to maintain a steady terminal voltage with load change. As mentioned before, they provide an additional excitation signal to the generator field that is proportional to the generator load currents. For example, the voltage developed across inductor L2A is proportional to the current in phase A of the generator bus. This voltage is additive with respect to the voltage of phase A, developed by potential transformer T6 that supplies the load winding of phase A of the power amplifier, 1SX. Thus, when the generator load current increases, the field excitation current through the load windings of 1SX will increase. This action tends to stabilize the terminal voltage by increasing the generated voltage with increase in armature current and internal armature impedance voltage drop.

CROSS-CURRENT-COMPENSATION ASSEMBLY

The cross-current-compensation assembly (fig. 4-3) consists of transformers CT1 and T9. and inductor L6 that are enclosed within a drip-proof case mounted on the a-c generator frame.

The cross-current-compensation assembly is used when two speed-regulation systems are operated in parallel to eliminate circulating cross currents between the two systems. One assembly is used for each of the two systems. A schematic diagram of the cross-current-compensation circuits is illustrated in figure 4-11. Current transformers CT1 are energized from phase C of the generator bus. Inductors L6 are connected across the secondaries of the current transformers to provide a low impedance path for the secondary current. The voltage drop across the inductors is applied to the primaries of transformers T9. The secondaries of T9 are connected between terminals 27 and 28 of phase C of the primaries of transformer T7 in the voltage detector circuit (fig. 4-10). Under single-system operation, a strap is connected between terminals 27 and 28, thereby shorting out transformer T9. Satisfactory single-system operation is obtained because only one generator is connected to the load bus, and the load-division circuit is not connected into the regulating system.

Before parallel operation is effected, the straps are removed from terminals 27 and 28 of the voltage detector, thereby inserting the secondary of transformer T9 of the cross-current compensation assembly in series with the primary of phase C of transformer T7 of the voltage detector circuit (fig. 4-10).

When the second generator is connected to the load bus by closing its circuit breaker, the circuit between the secondary of transformer T3 (fig. 4-3) and the parallel-operation relay coil. C, is completed through the auxiliary contacts. CB1 and CB2, of the two circuit breakers. When the parallel-operation relay coil is energized.

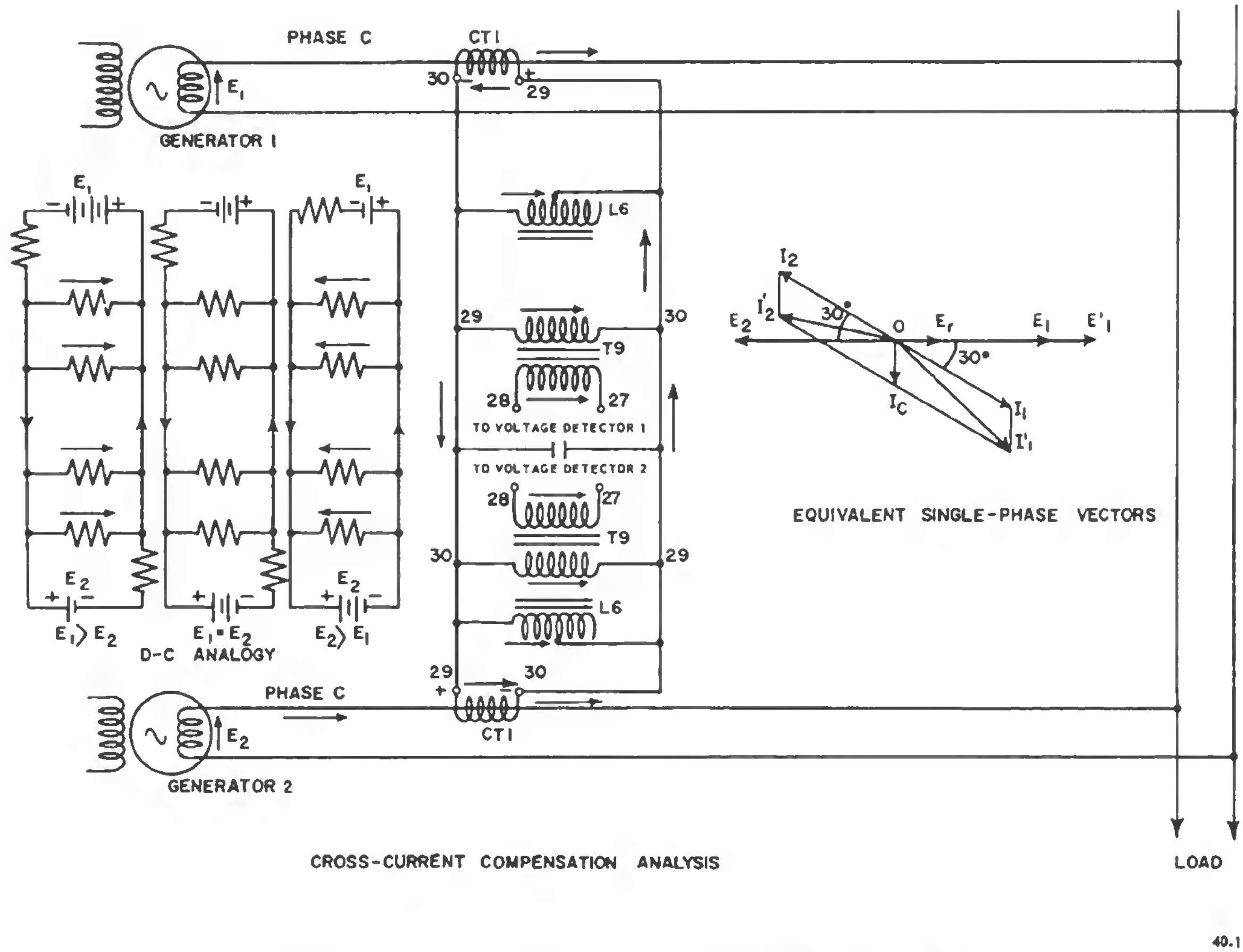

Figure 4-11.—Cross-current-compensation schematic.

the relay armature is activated and closes the two normally open contacts and opens the normally closed contact. The opening of the normally closed relay contact, POR, removes the shorting connection effected through the parallel-operation relay assembly (fig. 4-11) and connects together the two speed-regulation systems of each of the two cross-current-compensation assemblies.

Without cross-current compensation, improper field excitation on either generator would cause a circulating current to flow between the generator armatures with accompanying change of power factors. The circulating current would be accompanied by a lagging power factor on the over excited generator and a leading power factor on the under excited generator. Although the inherent regulation of these machines tends to correct the situation, the cross-current-compensation network provides a more sensitive device that aids materially in correcting the condition so that the circulating current is reduced to zero and the power factors of the generators are equalized.

When the proper condition exists, there is no circulating current between the generators, and the output voltage between terminals 27 and 28 of transformer T9 is zero. If, for example, the excitation of generator (1) is increased so that E_1 is greater than E_2 (fig. 4-11) the circulating current combines with the load component of current as shown in the vector diagram increasing the total current supplied by generator (1) from I_1 to I_1' and decreasing the total current of generator (2) from I_2 to I_2'. Thus, the core flux of CT1 in phase C of generator (1) increases, and that of CT1 in phase C of generator (2) decreases. This action causes the

secondary voltage of CT1 of generator ① to increase and that of CT1 of generator ② to decrease. The secondary of T9 of generator ① is connected to terminals 27 and 28 of phase C of the T7 primary of the voltage detector of generator ① so that the signal developed by T9 adds to the phase C voltage of T7. Thus, the increased input to the voltage detector results in an increased output signal of the voltage detector of generator ①. The action is like that previously described for over-voltage with single-generator operation. The voltage regulator lowers the field excitation of generator ①.

The secondary of T9 of generator ② is connected to terminals 27 and 28 of phase C of the T7 primary of the voltage detector of generator ② so that the signal developed by T9 subtracts from the phase C voltage of T7. Thus, the decreased input to the voltage detector results in a decreased output of the voltage detector of generator ② with increased field excitation being supplied by the voltage regulator. The simultaneous action of both voltage detectors quickly reduces the circulating current to zero.

If the conditions reverse and E_2 exceeds E_1, the direction of the resultant voltage and circulating current will reverse with respect to its direction in the vector diagram and in the circuit of figure 6-28. In this case the secondary voltage of T9 of generator ② will experience a phase shift of 180°, and the output signal of T9 to the voltage detector of generator ② will become additive with the voltage of phase C of T7. Thus, the voltage regulator of generator ② will weaken the field of generator ②. At the same time, the direction of the output voltage of T9 of generator ① will reverse, its direction with respect to that indicated in figure 4-11. This action will cause output of T9 to buck the voltage of phase C of T7 of generator ①, and the reduced output of the voltage detector will cause the field excitation of generator ① to be increased. Again, the simultaneous actions of both voltage regulators equalize the voltages, and the circulating current is reduced to zero. When this condition is effected, the outputs of the secondaries of T9 are reduced to zero.

A d-c analogy of the cross-current-compensation network is illustrated at the left of figure 4-11. When $E_1 = E_2$ (center), no current flows through the shunt resistors. This condition corresponds to the proper condition of parallel operation of the two generators.

METHODS AND PROCEDURES FOR MAINTAINING AND ADJUSTING VOLTAGE REGULATORS

Before attempting to adjust a voltage regulator, one should become thoroughly familiar with the function of the units and each of their components by studying the manufacturer's book for the equipment on board. In unfamiliar situations, regulators are serviced improperly, and this leads to further troubles which may be far more serious than the original fault.

PROTECTIVE MAINTENANCE

Inspect at regular intervals to ensure that all connections to the regulator and its magnetic amplifier are tight and that the surrounding areas are free of dirt, dust, and foreign matter. As with other vital equipment, the outside surface must be periodically vacuum cleaned or wiped with a clean dry rag to prevent accumulated dust from working into the inner spaces. Rectifier plates must be kept clean to facilitate proper cooling. When a vacuum cleaner is not available, dust may be removed with compressed air (30 lbs max.) or with hand bellows. Be certain that the compressed air, if used, does not contain grit or moisture. Remove oil with an approved nontoxic, nonflammable, cleaning fluid in accordance with chapter 6-413 of Bureau of Ships Technical Manual. Especially note that carbon tetrachloride must be avoided for cleaning purposes (although sometimes specified in manufacturers' books). The M-G sets should be operated to normal operating temperature every 24 hours to drive any moisture from the magnetic powder and prevent rust and corrosion from forming in the powder gap.

STATIC MAGNETIC AMPLIFIER MAINTENANCE

Two static type magnetic amplifiers are usually associated with the voltage regulator. Because of their sealed construction the individual amplifiers do not lend themselves to economical repair. If an internal defect is found, replace the amplifier assembly with the one provided in spare parts.

When one of the several magnetic amplifiers on board is suspected, check the continuity and

resistance of the various windings in accordance with data given in the manufacturer's instruction book. This application should be made as directed for interior communications installations in chapter 65 of the Bureau of Ship's Technical Manual.

To save time and trouble in making service adjustments, or performing tests for faults, the manufacturer often lists a series of tables. Each table shows the a-c voltage values (or current or resistance values when applicable) for certain voltage-regulator terminals identified on their accompanying wiring diagrams. Each table permits reaching "satisfactory" or "unsatisfactory" conclusions. If results are "unsatisfactory" note (1) which item is listed for replacement or (2) which adjustment is specified. However, if results were "satisfactory" proceed to the next listed test, and so on, until the defect has been located and cleared.

CORRECTIVE MAINTENANCE

When a defective part has been located visually or through use of the manufacturer's tables, it will be found that parts replacement is better than repair. Because many factors must be considered, such replacement may not be practical, as: whether spares are available; at what time the machine may be shut down; and the length of time it may be held out of service. The exact procedure in each case will be determined by the equipment and conditions at hand.

CHAPTER 5

GYROCOMPASSES (PART I)

The gyrocompass is standard equipment on all naval ships. Two types are in use: one manufactured by the Sperry Gyroscope Co. and the other manufactured by the Arma Corporation. Seven marks of Sperry and six marks of Arma gyrocompasses are in use at the present time. Modifications have been made to all marks of both types, however, and new marks are under development.

The scope of this chapter is limited mainly to a detailed discussion of the Sperry Mark XI Mod 6 gyrocompass, but in the early pages of the chapter gyrocompass errors pertinent to both Arma and Mercury ballistic type Sperry compasses are given brief treatment.

In addition this chapter presents information on self-synchronous Alidades and synchro signal amplifiers.

GYROCOMPASS DISTURBANCES

The direction indicated by a compass is read from the COMPASS CARD, the outer circumference of which is graduated in degrees (fig. 5-1). The graduations start with 0° at the north point and continue clockwise around the card to 360°, which coincides with the 0° point. The index line which indicates the ship's heading is called the LUBBER'S LINE. As the ship turns, the lubber's line turns with it. However, the card is controlled by the compass and remains stationary, always indicating north. The card graduation opposite the lubber's line on an errorless compass indicates the ship's heading in degrees clockwise from true north. Hence, the compass reads 90° for a true east course; 180° for a true south course; 270° for a true west course; and so forth.

If a ship is on a northerly course and turns east, the lubber's line turns clockwise around the card and the compass card reading changes to a higher number. However, if the compass is disturbed and an easterly error is introduced,

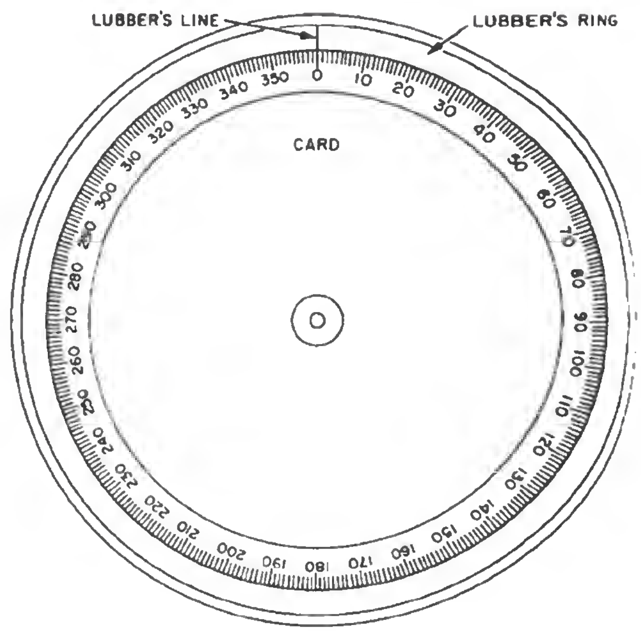

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Figure 5-1.—Gyrocompass card.

the card turns clockwise an amount equal to this error and the reading changes to a lower number. Only in drydock would this minor turning of the compass card be discernible.

Assume this easterly error is 2° and the ship is on a true course of 20°. The lubber's line has turned 20° clockwise to correspond to the true course. However, the card reads only 18° instead of 20° because the card has turned 2° clockwise with the easterly error.

When an easterly error occurs, the card reading is always less than the true course. Conversely, when a westerly error occurs the card reading is always more than the true course.

To correct for an easterly error in the Sperry compass the LUBBER's LINE is moved CLOCKWISE the amount of the error, whereas in the Arma compass the COMPASS CARD is moved COUNTERCLOCKWISE the amount of the error.

The elementary gyrocompass at the equator (as described in the I.C. Electrician 3 training course) appears to rotate about its horizontal axis once every 24 hours in the opposite direction to the rotation of the earth. This apparent rotation or tilt of the gyro horizontal axis is referred to as horizontal earth rate effect and varies with the cosine of the latitude being maximum at the equator and becoming zero at the poles.

Similarly, if the gyro is placed at the north or south pole it appears to rotate about its vertical axis once very 24 hours. The rotation about the vertical axis is referred to as vertical earth rate effect, and varies with the sine of the latitude, being maximum at the poles and becoming zero at the equator. In addition a gyrocompass aboard ship is subjected to many motions that tend to produce errors in the compass. These motions are caused by the ship's (1) linear speed over the surface of the ocean, tending to produce CONSTANT MOTION ERRORS: (2) changes in course and speed, tending to produce OSCILLATING ERRORS; and (3) roll and pitch, tending to produce QUADRANTAL ERRORS. Some errors can be eliminated by designing the compass to neutralize the influences that cause them. Other errors can be removed by calculating the amount of the error and correcting the compass to the true reading.

Constant motion errors comprise (1) tangent latitude error and (2) speed, course, latitude error.

TANGENT LATITUDE ERROR

The tangent latitude error is the direct consequence of the method used in the Sperry compass to damp the horizontal oscillations of the gyro axle. At the equator the compass settles in the meridian with its axle horizontal and with equal amounts of mercury in each tank. In any other latitude a torque must be applied to the gyro to keep it continually precessing or the gyro will leave the meridian because of its rigidity of plane and the earth's rotation. For the compass to reach a settling point, the north axle must be tilted upward in northern latitudes and downward in southern latitudes.

The upward tilt of the axle in northern latitudes causes an excess amount of mercury to collect in the south tanks. As previously explained, in I.C.E. 3 the point of connection between the mercury ballistic and the rotor case is offset a short distance east of the vertical axis to provide damping. Therefore, the excess mercury in the south tanks exerts a force through the offset connection that applies a torque simultaneously about both the horizontal and vertical axes. This action is called COMPOUND COMPRESSION. The downward precession tending to tilt the north axle below the horizontal is offset by the earth's rotation tending to tilt the axle upward. This action just prevents the torque produced by the mercury ballistic from bringing the axle horizontal and in the meridian. The north axle lags behind the meridian just enough to keep the gyro precessing at a constant rate.

In northern latitudes the north axle assumes a settling position slightly east of the true meridian with an upward tilt. In southern latitudes the north axle assumes a settling position slightly west of the true meridian with a downward tilt. As the angle of latitude increases, the displacement of the axle from the meridian increases. Finally, a position east of the meridian in northern latitudes or west of the meridian in southern latitudes is reached and the compass settles. This position occurs when the turning and tilting of the compass, caused by the action of the mercury ballistic through the offset connection, exactly balances the turning and tilting caused by the earth's rotation. The angle between the meridian and the settling position is called the TANGENT LATITUDE ERROR.

The tangent latitude error varies from zero at the equator to a maximum at high northern and southern latitudes. In any latitude other than the equator the Sperry compass settles with a slight tilt of the north axle and east or west of the true meridian. This tilt increases as the latitude increases. The tangent latitude error is approximately proportional to the tangent of the latitude in which the compass is operating.

Sperry Compass

When the Sperry compass has settled, the north axle is at rest in a virtual meridian with an upward or downward tilt. The small angle between the virtual meridian and the true meridan represents the tangent latitude error. This error is compensated for by an auxiliary latitude corrector that enables the lubber's line to be moved manually the exact amount of the error and in the proper direction. The corrector is calibrated in degrees of north and south latitude. Setting the latitude dial to the local latitude moves the lubber's ring and the transmitter rotary so that the compass card and the repeaters indicate

the true angle between the ship's heading and geographical north.

Arma Compass

The Arma compass has no tangent latitude error because it does not use compound precession. In the Arma compass the pendulous weight is in the line of the vertical axis and there is no offset connection as in the Sperry compass. Thus, the precession is about one axis only and the damping force of the oil tanks causes the Arma compass to settle in the meridian. Therefore, the gyro units bring the sensitive element to rest in the true meridian in all latitudes. However, the gyros used in the Arma compass come to rest in the true meridian with their north axles tilted slightly upward in northern latitudes and slightly downward in southern latitudes.

SPEED, COURSE, LATITUDE ERROR

The magnitude of the speed, course, latitude error depends upon the speed, course, and latitude of the ship. The gyrocompass tends to be north-seeking because north is at right angles to the west-to-east direction in which the earth's rotation carries the compass. The gyrocompass thus tends to settle with its axle at right angles to its plane of travel through space at all times.

A compass on the earth's surface is carried from west to east only when it is stationary with respect to the earth's surface, or when it is moving true east or true west. If any component of the course is north or south, the plane of motion is no longer west to east. Therefore, the compass will settle on a line at a small angle from true north. This line is called the APPARENT, or VIRTUAL MERIDIAN. The virtual meridian is a plane at right angles to the plane containing the path of the compass travel through space that the compass senses as the true meridian.

A ship at the equator is carried around the polar axis by the earth's rotation at a velocity of 900 knots. At any other latitude this velocity becomes 900 times the cosine of that latitude. If the ship is on a true west course its motion is opposite to that of the earth and subtracts from the speed of the earth. Conversely, if the ship is on a true east course its motion is in the same direction as that of the earth, and adds to the speed of the earth. The actual rate at which the compass is carried around the earth's polar axis thus decreases slightly on westward courses, and increases slightly on eastward courses. This increase or decrease in earth rate effect due to east-west speed is negligible and is not compensated for in either the Arma or ballistic type Sperry compasses.

If the ship travels on any other than a true east or true west course, however, the ship's motion and the earth's rotation combine to carry the compass in some direction other than west to east. In this case the compass seeks a new resting position away from the true meridian. This position is at right angles to the plane containing the path of the compass.

For example, if a ship at the equator steams true north at 20 knots (fig. 5-2), it carries the compass in a direction that is at right angles to the direction of the earth's rotation. In figure 5-2, Vector AA' represents the ship's direction and speed which is 20 knots. Vector AB represents the direction and speed of the earth's surface which is 900 knots at the equator. The vectors are not drawn to scale because AA' is only about 2 percent of the length of vector AB and the resulting parallelogram would be too small to indicate clearly the individual components. Resultant vector AC represents the total absolute speed of the compass and the direction in which it is being carried in space around the earth's polar axis (earth's axis of spin).

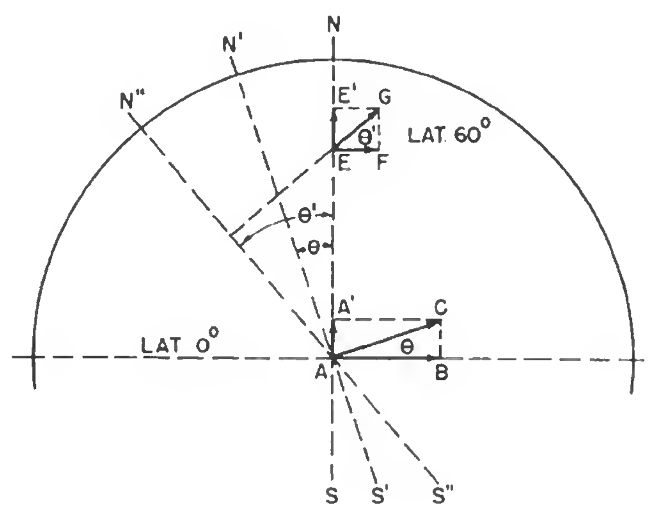

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Figure 5-2.—Speed, course, latitude error.

The true meridian is along line NS which is perpendicular to vector AB. The apparent or virtual meridian is along line N'S' which is perpendicular to vector AC. Vector AC lies in the plane which contains the path of the compass motion through space. The gyro axle therefore settles on the virtual meridian, N'S', and not on the true meridian, NS. The true north is east of the indicated north by angle θ, where

$$\theta = \tan^{-1}\left(\frac{BC}{AB} = \frac{20}{900} = 0.0222\right) = 1.27^\circ$$

Thus, $\theta = 1.27^\circ$ for a speed of 20 knots on a true north course. Angle θ is purposely exaggerated in the figure to clearly indicate the speed, course, latitude error.

As another example, if a ship at 60° north latitude is steaming true north at 20 knots (fig. 5-2), Vector EE' represents the ship's direction and speed which is 20 knots. Vector EF represents the direction and speed of the earth's surface which is 450 knots at 60° north latitude. Resultant vector EG represents the total absolute speed of the compass and the direction in which it is being carried in space around the earth's polar axis. The resultant virtual meridian for the ship's speed, course, and latitude (as indicated in figure 5-2) is at right angles to vector EG and is along line N''S''. The compass tends to align itself with this virtual meridian.

The true north is east of the indicated north by angle θ', where

$$\theta' = \tan^{-1}\left(\frac{FG}{EF} = \frac{20}{450} = 0.0444\right) = 2.56^\circ$$

Thus, $\theta' = 2.56^\circ$ for a speed of 20 knots on a true north course. Angle θ' is exaggerated to indicate the error. If the ship's speed is reduced, however, the error will be less. If the ship's speed is increased, the error will be more.

If a ship at the equator is steaming true south at 20 knots, the deviation of the compass axle is toward the opposite side of the true meridian. In other words, true north is to the west of that indicated by the compass. However, in practice the speed, course, latitude error (SCLE) is determined from the equation—

$$\text{SCLE} = \frac{0.0637 \times \text{speed in knots} \times \text{cosine of the course}}{\text{cosine of the latitude}}$$

where 0.0637 is a constant for converting the error into degrees.

The speed, course, latitude error is westerly if any component of the ship's course is north. Conversely, the speed, course, latitude error is easterly if any component of the ship's course is south. The magnitude of this error is proportional to the latitude, the speed, and the course of the ship. The direction of this error is determined by the ship's course. The effects of the speed, course, latitude error are similar for both Sperry and Arma Compasses, and corrector mechanisms are provided on both compasses to compensate for these effects.

Sperry Compass

The Sperry compass is provided with a speed and latitude corrector to compensate for the speed, course, latitude error in addition to the auxiliary latitude corrector that compensates for the tangent latitude error. This speed and latitude corrector consists of a stationary plate (fig. 5-3) on which are engraved several speed curves, and a movable plate on which are engraved various latitudes. The movable plate

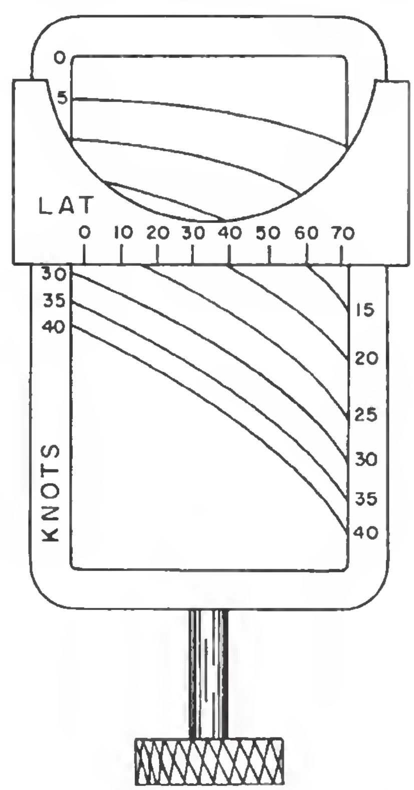

Figure 5-3.—Sperry speed and latitude corrector

is controlled by means of an adjusting knob. The corrector is set by turning the adjusting knob until the mark indicating the local latitude intersects the speed curve corresponding to the ship's speed. When set to the proper speed and latitude, the corrector automatically shifts the lubber's line in the right direction and the proper amount to compensate for ship's speed and earth rate at the local latitude.

The effect of the ship's course on the speed, course, latitude error is automatically compensated for by an eccentric groove, or COSINE RING (fig. 5-4), cut into the upper surface of the large azimuth gear which is located below the compass card. As the ship turns around the compass, the cosine ring moves a follower, or COSINE CAM, forward or aft. The movement of the cam operates a system of levers that automatically shifts the lubber's line the proper amount and in the right direction to compensate for ship's course.

On a northerly course, the cam is in its most forward position and the maximum correction for speed and latitude is applied to the lubber's line.

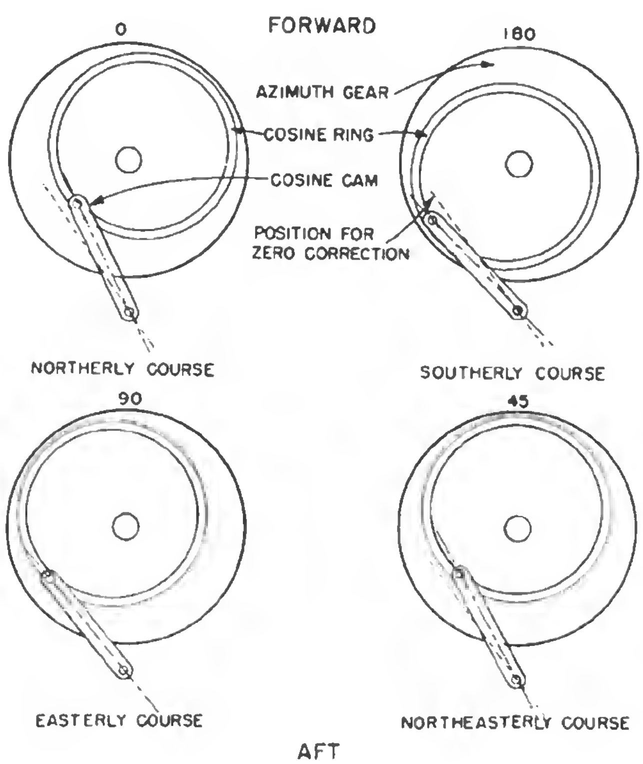

Figure 5-4.—Sperry cosine ring.

On a southerly course, the cam is in its most aft position and the maximum correction is again applied but in a direction opposite to that for a northerly course.

When the heading is east or west, the cam is in a position halfway between that for north or south, and no correction is applied. On an intermediate course, the cam is in a position between these extremes and the correction applied is of the proper value for the ship's heading.

The amount of correction applied for any heading is proportional to the cosine of the angle between true north or true south and the ship's course. For this reason the eccentric ring and the follower are called the cosine ring and cosine cam respectively.

When the speed and latitude corrector is set to the proper speed and latitude, and is combined with this automatic course compensating feature, the total resultant correction for the speed, course, latitude error is transmitted to the lubber's line. The lubber's line then moves automatically to port or starboard the exact amount of the resultant correction. The movement of the lubber's ring shifts the rotors of the synchro transmitters so that the repeaters and the compass cards indicate the true heading on all courses.

Arma Compass

The Arma speed and latitude correction mechanism consists of a metal plate on which is engraved the correction in degrees to be applied for any speed in any latitude. The correction for the speed and latitude is applied to the compass by means of a correction knob which carries a scale graduated in degrees. The speed correction mechanism is set by turning the knob until the scale shows the proper correction as indicated on the metal plate.

The effect of the ship's course on the speed, course, latitude error is automatically compensated for by the eccentric bearing and fork (fig. 5-5) which are geared to the followup coil. When the correction due to speed and latitude is introduced by means of the correction knob, it is applied to the followup system through the eccentric bearing and fork which automatically corrects for the error on all headings by moving the followup coil. Movement of the followup coil, causes the followup motor to operate and move the compass card and repeaters to indicate the angle between the ship's heading and true north.

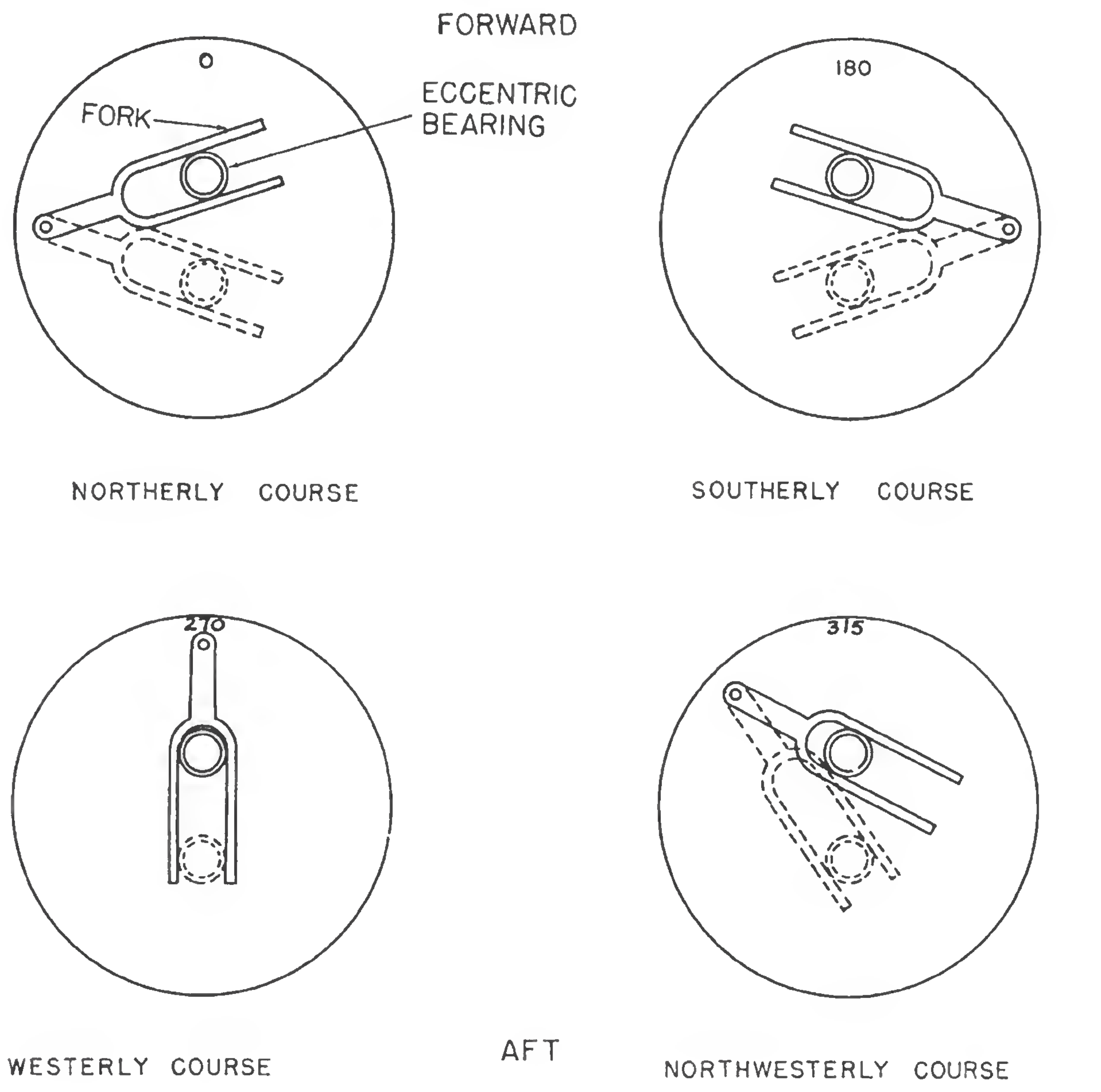

Figure 5-5.—Arma eccentric bearing and fork.

The fore-and-aft position of the bearing is controlled by the setting of the correction knob. On a northerly or southerly course, the motion of the eccentric bearing in a fore-and-aft direction rotates the fork about its pivot and applies the maximum correction. On an easterly or westerly course, no correction is applied because the motion of the eccentric bearing in a fore-and-aft direction does not rotate the fork. On an intermediate course, the eccentric bearing is between these extremes and the correction applied is of the proper value for the ship's heading.

Some models of the Sperry and Arma compasses are equipped with automatic mechanisms that apply the correction for the speed error. These mechanisms are provided with synchro receivers that receive an indication of the ship's speed from the underwater log, and a followup

motor that applies this quantity to a lever type multiplier.

OSCILLATING ERRORS

Oscillating errors comprise (1) ballistic deflection error and (2) ballistic damping error.

BALLISTIC DEFLECTION ERROR

The ballistic deflection error is dependent upon the rate of change of the ship's speed or course. It is a transient error that is introduced into the compass only during changes of speed or course. The gyrocompass is subjected to the action of the forces of inertia when a ship changes speed or course. The inertia of an object causes it to resist any attempt to change its position if it is at rest, or to resist any attempt to change its speed or direction if it is in motion. This principle is demonstrated by the manner in which passengers on a street car or bus are thrown backward when the vehicle starts, and forward when it stops. The mercury in the Sperry mercury ballistic and the pendulous weight of the Arma compass are subjected to a similar force when the ship's speed or course is changed.

When a ship steaming north increases its speed, the mercury in the mercury ballistic is forced aft, or to the south, by the effect of its inertia. A portion of the mercury in the north container flows to the south; the south container becomes heavier and a downward force of gravity is exerted on the south end of the rotor axle. A similar force acts on the pendulous weight of an Arma compass and pushes south at the bottom of the rotor. This is equivalent to a downward force on the north end of the axle.

In either case, fortunately, the direction of the force is such as to cause the compass to precess toward its new settling position. The force is exerted during the time in which the change is being made and its strength is proportional to the rate of the change. Thus, a rapid change in speed results in a comparatively large force being exerted for a short time, whereas during a more gradual change of the same amount results in a smaller force being exerted for a longer time. The total precession in either case is the same. The precession resulting from such a force is called BALLISTIC DEFLECTION. When the ballistic deflection is exactly equal to the change in the speed, course, latitude error for a change in speed or course, the compass settles quickly in the virtual meridian and there is no error in its indication. When the ballistic deflection is not equal to the change in the speed, course, latitude error, the resulting error is called the BALLISTIC DEFLECTION ERROR. This error consists of a series of decreasing oscillations across the normal settling point of the compass. Therefore, it cannot be corrected by shifting the lubber's line or the compass card.

The factors that control the magnitude of the speed, course, latitude error also control the amount of the ballistic deflection and the length of the undamped period of the compass. If the gyroscope is designed properly, the ballistic deflection for any change of speed or course can be made equal to the change in speed, course, latitude error. Such design results in a normal period of approximately 85 minutes. Since the period varies with the latitude, a compass that has no ballistic deflection error in one latitude will have such an error in another latitude. This condition can be corrected if one or more of the controlling factors are made variable so that the period can be adjusted to the same level for all latitudes.

The combined effect of the speed, course, latitude error and the ballistic deflection error on the accuracy of the gyrocompass is illustrated in figure 5-6. A ship steaming true north at 20 knots changes its speed to 10 knots during a 5-minute period. On a northerly course, the gyro will have a speed, course, latitude error. The gyro axle will point west of the true meridian by an amount dependent upon the ship's speed and latitude.

The angles are exaggerated in figure 5-6 to clarify the discussion. Line ON represents the direction of true north and line ON' represents the direction in which the gyro axle aligns itself when the ship's speed is 20 knots. Angle NON' represents the speed, course, latitude error. Line ON'' represents the direction in which the gyro axle points when the speed has been reduced to 10 knots. Angle NON'' is the new speed, course, latitude error.

As the speed is being reduced, the gyro axle tends to move eastward to its new resting position because of the meridian seeking property of the compass. The ballistic deflection also causes the gyro axle to precess eastward. Assume that the ballistic action causes the gyro axle to precess to OC, overshooting ON''. When the ship settles to its 10-knot speed, the

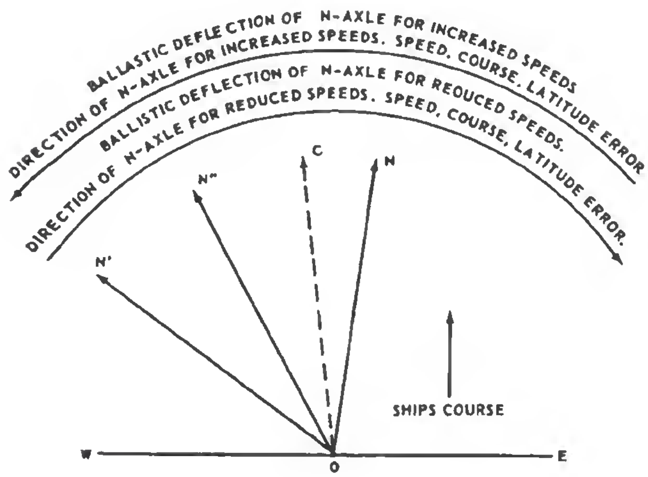

Figure 5-6.—Speed, course, latitude error and ballistic deflection error.

acceleration force subsides and the gyro axle begins to precess westward and across ON". It continues this oscillation about ON" with diminishing amplitude and finally come to rest along ON". Note that the ballistic deflection is always in the same direction as the change in the speed, course, latitude error for all changes of speed on any course.

Under certain conditions, the movement caused by the ballistic deflection causes the compass to move to its settling position at the same rate as the change in speed, course, latitude error. If this occurs, the ballistic deflection swings the axle to its new settling position, and with no accompanying tendency for the gyro axle to oscillate when the ship assumes a steady speed. The gyro axle points in its new direction in a dead-beat manner. The effect of the ballistic deflection is then confined only to the period during which the speed is being changed.

Once the characteristics of the compass are determined, the magnitude of the ballistic deflection error is dependent upon the (1) direction of the ship's course and (2) rate of change of speed. It is not affected by the latitude. The acceleration force is the same in all latitudes for a given course and rate of change of speed. However, the magnitude of the speed, course, latitude error does vary with the latitude. If these factors are considered in the design of the compass, the period of oscillation at one particular latitude can be selected so that the ballistic deflection can be made just equal to the difference between the speed, course, latitude errors for any changes in speed or course at this latitude. If this selection is accomplished, the error due to ballistic deflection is compensated for and the period of compass oscillation maintained at the proper value for the particular latitude chosen.

Sperry Compass

Sperry compasses that are used for navigation are constructed with a fixed undamped period of about 85 minutes at 40.7° latitude. Hence, there is no ballistic deflection error at 40.7° latitude with this period. In fact, the error at any latitude is small and does not affect the accuracy of navigation to any great extent.

Compasses that are used for fire control must maintain a constant and accurate indication of the ship's heading. This condition is accomplished by maintaining a period of about 85 minutes in all latitudes. On these compasses the mercury ballistic is constructed so that the tanks can be set closer to, or farther from, the horizontal axis about which they operate. At the equator, the tanks are set in their innermost position. For north and south latitudes where the period would normally be longer, the tanks are set farther out. This adjustment provides the additional torque necessary to cause a faster rate of precession and thereby shorten the period. To set the ballistic for any latitude, a knob mounted on the ballistic frame is turned until an attached scale indicates the correct latitude.

Arma Compass

The Arma navigational compass, like the Sperry, is constructed with a fixed undamped period of about 85 minutes at 40.7° latitude.

In Arma fire control compasses the period is kept constant at about 85 minutes in all latitudes by adjusting the rotor speed. The rotors spin at their maximum speed at the equator, and at lower speeds in north or south latitudes. The gyro rigidity of plane decreases with the speed. The adjustment on the Arma compass is made by setting a knob on the control panel to the desired latitude. This knob adjusts the rotor speeds by varying the speed of the gyro supply motor-generator and thus the frequency of the 3-phase voltage applied to the gyro stators.

BALLISTIC DAMPING ERROR

Oscillations are damped in the Sperry and Arma compasses by partly suppressing the precession caused by the action of the mercury ballistic or the pendulous weight. The slight error introduced by the damping arrangement during changes in speed or course is called the BALLISTIC DAMPING ERROR. This error, like the ballistic deflection error, is oscillatory and of a temporary nature.

The Sperry compass uses a mercury ballistic connected slightly east of the true vertical axis of the gyro to damp the oscillations across the meridian, or about the vertical axis. The Arma compass uses an oil ballistic to damp the oscillations of the gyro about the vertical axis. These damping arrangements cause the gyros to reach a settling point. However, both systems produce a transient error in the compass when a ship makes a rapid change in speed or course. Changes in speed produce ACCELERATION FORCES; whereas changes in course produce CENTRIFUGAL FORCES. Both of these forces have a similar effect on the compass.

A ship steaming true west at 20 knots suddenly executes a 90° turn to the right (fig. 5-7). During the turn a centrifugal force is applied to every part of the compass, including the ballistic. In the Sperry compass this action causes an excess of mercury to collect in the south tanks of the ballistic at A. Because of the offset connection of the mercury ballistic, the excess mercury that has collected in the south tanks exerts a torque about the vertical axis in addition to the one taking place about the horizontal axis during the turn. This torque about the vertical axis produces a downward tilt of the north axle at B as a result of precession. This tilt of the gyro axle causes an oscillation to start as the centrifugal force diminishes to zero at C. As a result the gyro precesses and leaves the meridian. This oscillation on a compass with a damped period of about 85 minutes becomes maximum at D, 21 minutes after the change in course is completed, and finally comes to rest in about 2 hours.

The oil in the oil ballistic of the Arma compass is subjected to the same centrifugal force on changes in course. An excess of oil collects in one tank. This action causes a torque and a consequent movement of the gyro axle from the meridian. The magnitude of this error is small and averages not more than 1°.

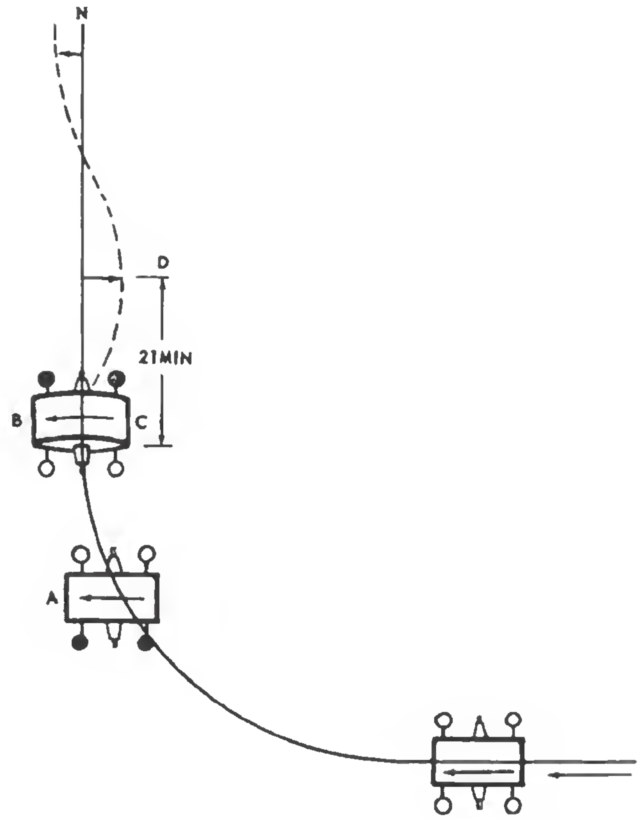

Figure 5-7.—Ballistic damping error.

Sperry Compass

The ballistic damping error is eliminated in the Sperry fire control gyrocompass by means of an automatic damping eliminator. This device automatically moves the mercury ballistic connection arm from the offset position to the true vertial axis of the gyro whenever a change in the ship's course is greater than 15° and faster than 40° per minute, or whenever the ship's speed changes at 2 knots per minute. Moving this offset connection to the true vertical axis eliminates the torque about this axis caused by the centrifugal force and prevents the compass from going through a damped oscillation.

Arma Compass

The ballistic damping error is eliminated in the Arma compass by closing a valve in the pipe line between the oil damping tanks. Electromagnetic devices called DAMPING ELIMINATORS are used for this purpose. They are

automatic in their action for changes above an established minimum which is the same as that for the Sperry compass. Pushbuttons are provided for manual operation of the damping eliminators.

QUADRANTAL ERRORS

A gyrocompass aboard a rolling or pitching ship is subjected to acceleration forces and centrifugal forces. Acceleration forces are caused by the inertia of the gyrocompass tending to oppose the change in the direction of motion at the end of a roll or pitch. Centrifugal forces tend to move the gyrocompass away from the center about which the ship is rolling or pitching.

When the gyro axle is parallel to the ship's heading (true north or true south course) or at right angles to the ship's heading (true east or true west course), the forces of rolling or pitching have no effect on the gyro axle. On all courses between the cardinal headings (true north, south, east, or west), or quadrantal courses, the forces of rolling or pitching affect the gyro axle. Hence, the resulting errors in compass indications are called QUADRANTAL, OR INTERCARDINAL, ERRORS.

ACCELERATION FORCES DUE TO ROLL OR PITCH

A gyrocompass is suspended by means of gimbal rings in its binnacle so that it is free to take almost any position with respect to the binnacle. The compass can hang vertically regardless of the ship's position and it can swing out of a vertical position when the acceleration forces caused by rolling or pitching act on it.

A pendulous gyrocompass viewed from the south is shown in figure 5-8, A. The rotor case, R, corresponds to the inner ring of the gyroscope and supports the bearings on which the rotor spins. It is mounted on horizontal bearings in the vertical ring, A, which corresponds to the outer gimbal ring of the gyroscope. The entire assembly hangs from the support, S, with freedom to swing in any direction and to turn about a vertical axis.

When the support, S, is accelerated to the right, or east, the compass assumes the position shown in figure 5-8, B, and the weight, W, is west of the vertical. Conversely, when the support is accelerated to the left, or west, the compass assumes the position shown in figure 5-8, C, and the weight, W, is east of the vertical.

The same gyrocompass viewed from the west is shown in figure 5-9, A. When the support is accelerated to the right, or south (fig. 5-9, B), and when the support is accelerated to the left, or north (fig. 5-9, C), rigidity of plane prevents the rotor from swinging out of the vertical. However, the inertia of the weight, W, attempts to cause such a swing, and exerts acceleration forces, F, around the horizontal axis.

When a ship on a true north course is rolling, the relative positions of the rotor and vertical ring as viewed from the south are shown in figure 5-8. All swinging occurs in the plane in which the rotor is spinning. Because there is no attempt to change this plane of rotation, there is no precession. Thus, there is no error on a true north or true south course.

When the ship on a true east course is rolling, the relative positions of the rotor and vertical ring as viewed from the west are shown in figure 5-9. In this case torques are exerted about the horizontal axis, alternately clockwise and counterclockwise, by the acceleration forces, F. The natural period of oscillation of the compass is so large (85 minutes) in comparison to the period of ship's roll (5 to 10 seconds), that these torques reverse and cancel each other on successive rolls. Thus, there is no error on a true east or true west course.

When the ship on a northeasterly course is rolling, the compass is subjected to a combination of the effects that occur on true north and true east courses. When the ship rolls to starboard, the acceleration is southeast. Conversely, when the ship rolls to port, the acceleration is northwest.

During the starboard roll, as viewed from the southwest, the compass assumes a position that is a combination of those shown in figures 5-8, B, and 5-9, B. The effect of the easterly component of the acceleration to the southeast is represented by the position shown in figure 5-8, B. The effect of the southerly component is represented by the position shown in figure 5-9, B. The easterly component swings the weight, W, out of the vertical. The southerly component causes the acceleration forces, F, to act at a time when the weight, W, is out of the vertical, and causes torques to be exerted about both the horizontal and the vertical axes.

To visualize the action of the acceleration forces, F, rotate the position shown in figure

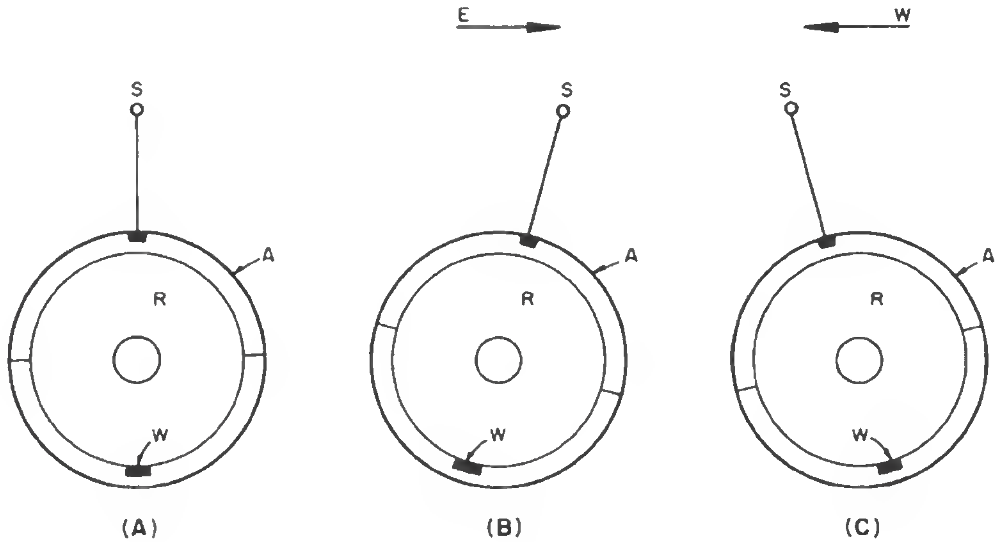

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Figure 5-8.—Effect of rolling on a true north course.

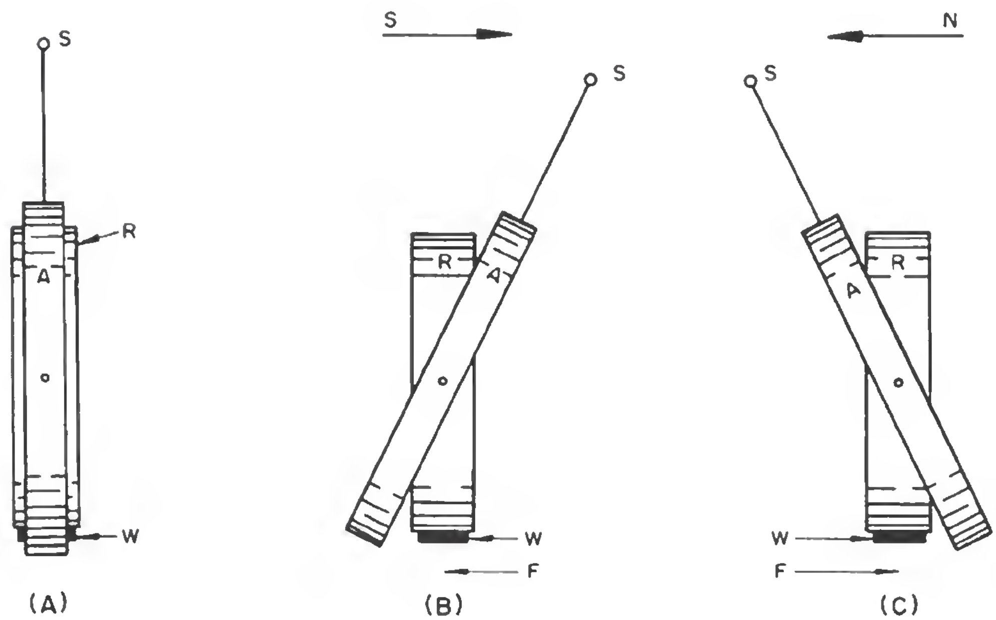

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Figure 5-9.—Effect of rolling on a true east course.

5-9, B, one-quarter turn to the left about the vertical axis, so that the rotor is viewed from the south as it is in the position shown in figure 5-8, B. The forces, F, are then rotated through 90° and are directed away from the observer. A force acting on the weight, W, in a direction away from the observer will, when it is displaced from the vertical as shown in figure 5-8, B, exert a clockwise torque about the vertical. It will also exert a torque about the horizontal tending to raise the north end of the rotor axle.

The torque developed about the horizontal axis on the starboard roll tends to raise the north end of the rotor axle, and on the port roll tends to raise the south end of the rotor axle. These effects are opposite and cancel each other on successive rolls. The torques about the vertical axis are clockwise on both the starboard and port rolls. Even if the torque produced on one roll is quite small, the successive impulses on many rolls being in the same direction, are cumulative and can cause a considerable error.

If a ship is steering a course in the northeast or southwest quadrant, the deviation is always to the east. Conversely, if a ship is steering a course in the northwest or southeast quadrant, the deviation is always to the west. The effect of pitching on quadrantal courses causes an error opposite to that produced by rolling. Thus if a ship is both rolling and pitching the quadrantal error is less than if rolling alone is present.

Sperry Compass

If a compass is improperly balanced so that it is either top-heavy or pendulous, a disturbing effect results when the ship rolls or pitches on an intercardinal heading. When the Sperry Compass is properly balanced, the sensitive element is neither top-heavy nor pendulous.

The mercury ballistic is mounted with its center of gravity coincident with the horizontal axis of the gyro element. Consequently, it is in neutral equilibrium when the mercury is equally distributed in each tank. Therefore, acceleration forces resulting from the roll or pitch of the ship have no disturbing effect on the Sperry gyro when it is dynamically balanced about the horizontal axis.

Arma Compass

Acceleration errors cannot be prevented in the Arma compass by making it nonpendulous because this compass depends for its operation on the principle of a pendulous gyro. However, the acceleration forces due to roll or pitch on intercardinal courses are neutralized in the Arma compass by east-west stabilization of the sensitive element. This stabilization is accomplished by using two gyros mounted on the sensitive element frame at an angle of approximately 40° with respect to the north-south axis (fig. 5-10).

The two gyros oppose any attempt of the sensitive element to tilt in an east-west direction and a portion of the directive force of the gyros remains in the north-south plane so that the sensitive element seeks the meridian. If the sensitive element attempts to tilt in the north-south direction, the two gyros precess in the same direction and carry the sensitive element with them. To make certain that the sensitive element follows the gyros exactly when they precess in the same direction and to prevent the sensitive element from turning at all when the gyros precess in opposite directions, the two

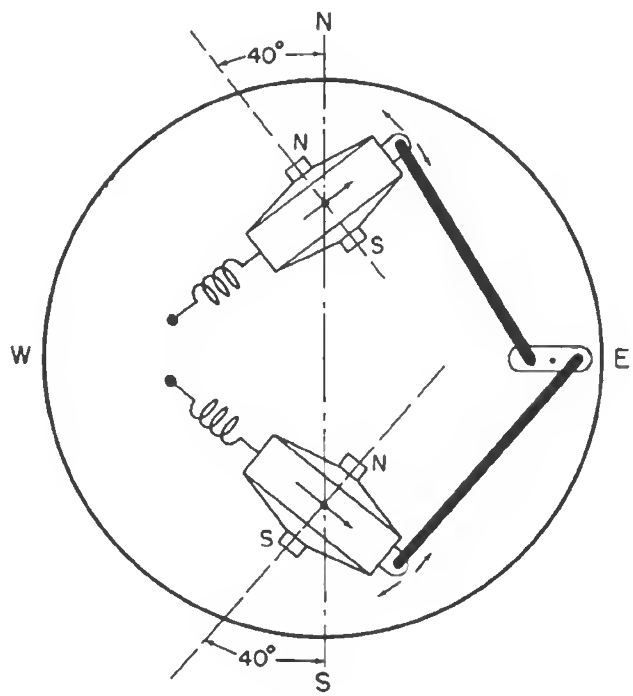

Figure 5-10.—Arma arrangement and coupling of gyro rotors.

gyros are connected by a linkage. This linkage ensures their turning relative to the sensitive element only in equal and opposite angles. The centering springs hold the two gyros in their normal resting positions from the north-south plane when there is no disturbing force tending to deflect them.

The reason for having the gyros inclined and coupled by the linkage is to eliminate the intercardinal error by preventing the sensitive element from swinging in an east-west direction. When the frame tends to swing, the gyro units precess around their vertical axes in equal and opposite angles. As the ship rolls, the swinging tendency is first in one direction and then in the other, causing the gyros to turn back and forth through a small angle. The compass reading is not affected because this action does not turn the sensitive element as a whole.

CENTRIFUGAL FORCES DUE TO ROLL OR PITCH

Intercardinal rolling or pitching resolves itself partly into centrifugal forces. These forces act upon the entire mass composing the movable element of the gyrocompass. Centrifugal forces are a maximum when the masses cross the vertical because the masses are then moving with the greatest velocity. The effect is the same for either direction of swing. If the mass is not uniformly distributed about every axis that is perpendicular to the axis of suspension, the compass tends to turn so that the axis of greatest moment of inertia is in the axis of swing. A simple demonstration of this phenomenon is to swing a watch on its chain. Regardless of the position of the watch when it starts swinging, it soon turns so that its flat surfaces are in the plane of swing.

When the axle of a gyrocompass rotor is north and south, it has much more weight in the east-west plane than in the north-south plane. When it is subjected to the centrifugal force resulting from the rolling or pitching of a ship, it attempts to align its east-west plane in the plane of roll or at right angles to the course.

The attempt of the gyro rotor to align itself in the plane of the ship's roll causes a torque about the vertical axis and can cause an error in the compass indication. On a true north or true south course, the east-west plane of the rotor is already in the plane of the roll. On a true east or true west course, the east-west plane of the rotor is at right angles to the plane of the roll and the torque attempting to turn it clockwise is the same as the torque attempting to turn it counterclockwise. These equal and opposite torques cancel each other. Thus, centrifugal forces can cause compass errors only on quadrantal courses.

Sperry Compass

The effect of centrifugal forces is neutralized in the Sperry compass by compensator weights mounted on the vertical ring at right angles to the plane of the greatest moment of inertia. These weights are mounted in brackets that support one weight opposite each end of the rotor axle. The moment of inertia is made equal about all horizontal axes in the plane of the gimbal centers by adjusting the weights to the proper position. Hence, centrifugal forces have no effect on the Sperry compass. The compensator weights are attached to the vertical ring in order that the sensitive element will be a truly hemispherical mass.

Arma Compass

The effect of centrifugal forces is eliminated in the Arma compass by maintaining a uniform distribution of the masses of the sensitive element about the vertical axis. In other words, in any plane parallel to, and including the vertical axis, the same mass is distributed on each side of the vertical axis and the centers of gravity of the masses are the same distances from the vertical axis. This even distribution of mass in conjunction with the mercury flotation prevents torque about the vertical axis. Thus, centrifugal forces have no effect on the Arma compass.

SPERRY MK XI MOD 6 GYROCOMPASS

The Sperry Mk XI Mod 6 gyrocompass is a fire control compass used principally on destroyers. The development of the Sperry Mk 19 and Mk 23 compasses has brought about improvements and major design changes in gyrocompasses. However, the Mk XI Mod 6 compass still is considered the standard U. S. Navy destroyer gyrocompass and is therefore included as a major portion of this chapter.

The complete gyrocompass system consists of the master compass, the control system, alarm system, followup system, and the transmission system.

The master compass (figs. 5-11 and 5-12) includes five major components: (1) Sensitive element, (2) Mercury ballistic, (3) phantom element, (4) spider, and (5) binnacle and gimbal rings (not shown).

SENSITIVE ELEMENT

The sensitive element (fig. 5-13) is the north seeking gyroscopic element of the master compass. It is suspended within the phantom ring (fig. 5-11) and consists essentially of the gyro unit, vertical ring, compensator weights, followup indicator (not shown) and suspension.

Gyro Unit

The gyro unit provides the directive force for the sensitive element that makes the compass north-seeking. The unit consists of the rotor and case (fig. 5-14). The gyro rotor (fig. 5-14, A) is a steel forging 10 inches in diameter, 4 1/2 inches wide, and weighing approximately 72 pounds. It is machined and balanced to rotate on special ball bearings with a minimum vibration at a normal speed of 11,000 rpm. The gyrorotor construction includes a laminated squirrel cage rotor fitted inside the rim on both faces of the gyro wheel.

The gyro case (fig. 5-14, b and c) construction includes a 3-phase, double-stator winding, one stator being mounted in each half of the case. Horizontal (ball) bearings on which the rotor spins are mounted in the rotor case.

The case is made airtight and the rotor operates in a vacuum (26 to 30 inches of mercury) to reduce the friction caused by air resistance. A vacuum gage (not shown) is mounted near the top of the north half of the case to indicate the degree of vacuum.

A spirit level (gyrocase level in fig. 5-13) is mounted on the lower part of the north side of the case to indicate the tilt of the rotor.

A small window (not shown) is provided in the south half of the case through which the spinning rotor can be observed during starting.

Vertical Ring

The vertical ring (fig. 5-13) is attached to a wire suspension from the head of the phantom element. An upper and lower guide bearing prevent the vertical ring from moving laterally within the phantom ring.

The upper guide bearing has its outer race secured in the phantom ring. The inner race is formed by the lower stud of the suspension. The lower guide bearing has its outer race secured in the bottom of the vertical ring. The inner race is formed by a vertical stud that projects upward from the bottom of the phantom ring.

A gyro case lock (fig. 5-13) is provided to prevent the gyro case from tilting about its horizontal axis when the compass is not operating. This latch should be disengaged only when the rotor is running at normal speed. It is located on the lower part of the south side of the ring.

A vertical ring lock (fig. 5-13) is provided to keep the vertical ring in line with the phantom ring when the compass is not operating. This lock prevents the wire suspension from acquiring a permanent set which would affect the settling point of the compass.

Compensator Weights

The compensator weights (fig. 5-13) are supported by two frames that are attached to the vertical ring. These frames project out beyond each end of the rotor axle. The weights are mounted concentrically on their studs, and their positions can be adjusted in the direction of the axis of the gyro rotor. The function of the weights is to provide an even distribution of the weight of the gyrocompass about the vertical axis.

The armature of the signal pick-off or follow-up transformer is attached to an arm that protrudes horizontally from the upper part of the south compensator-weight frame (fig. 5-13).

Followup Indicator

The followup indicator (not shown) determines the position of the phantom element with relation to the sensitive element. This indicator consists of a scale and a pointer. The scale is attached to the phantom element below the spider table and the pointer is attached to the north compensator weight frame. The scale is calibrated in degrees with the center marked "O". Thus, a misalignment between the phantom element and sensitive element is indicated in degrees.

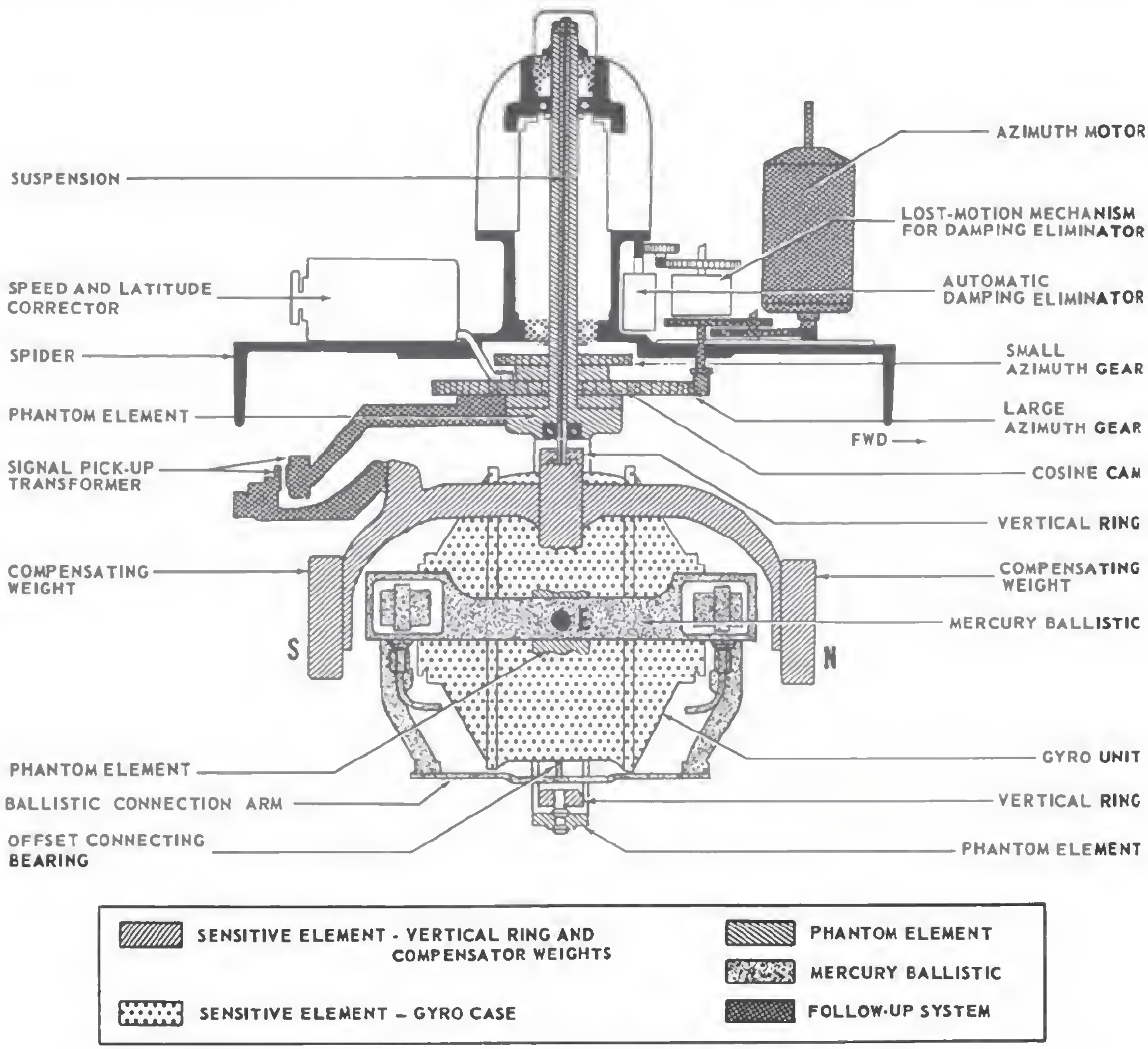

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Figure 5-11.—East elevation of Sperry Mk XI Mod 6 master gyrocompass.

Suspension

The suspension (fig. 5-13) suspends the entire sensitive element from the phantom element. It consists of a number of small steel wires secured at the upper end to a support stud and at the lower end to a guide stud. A nut and check nut secures the support stud to the phantom element, and provides a means to adjust the sensitive element, vertically. The guide stud passes through a hole in the upper part of the vertical ring and is clamped to the ring by a nut. This stud also serves as the inner race of the upper guide bearing of the ring.

MERCURY BALLISTIC

The mercury ballistic (fig. 5-15) is that group of parts which applies the gravity-controlling force to the gyro unit and makes it

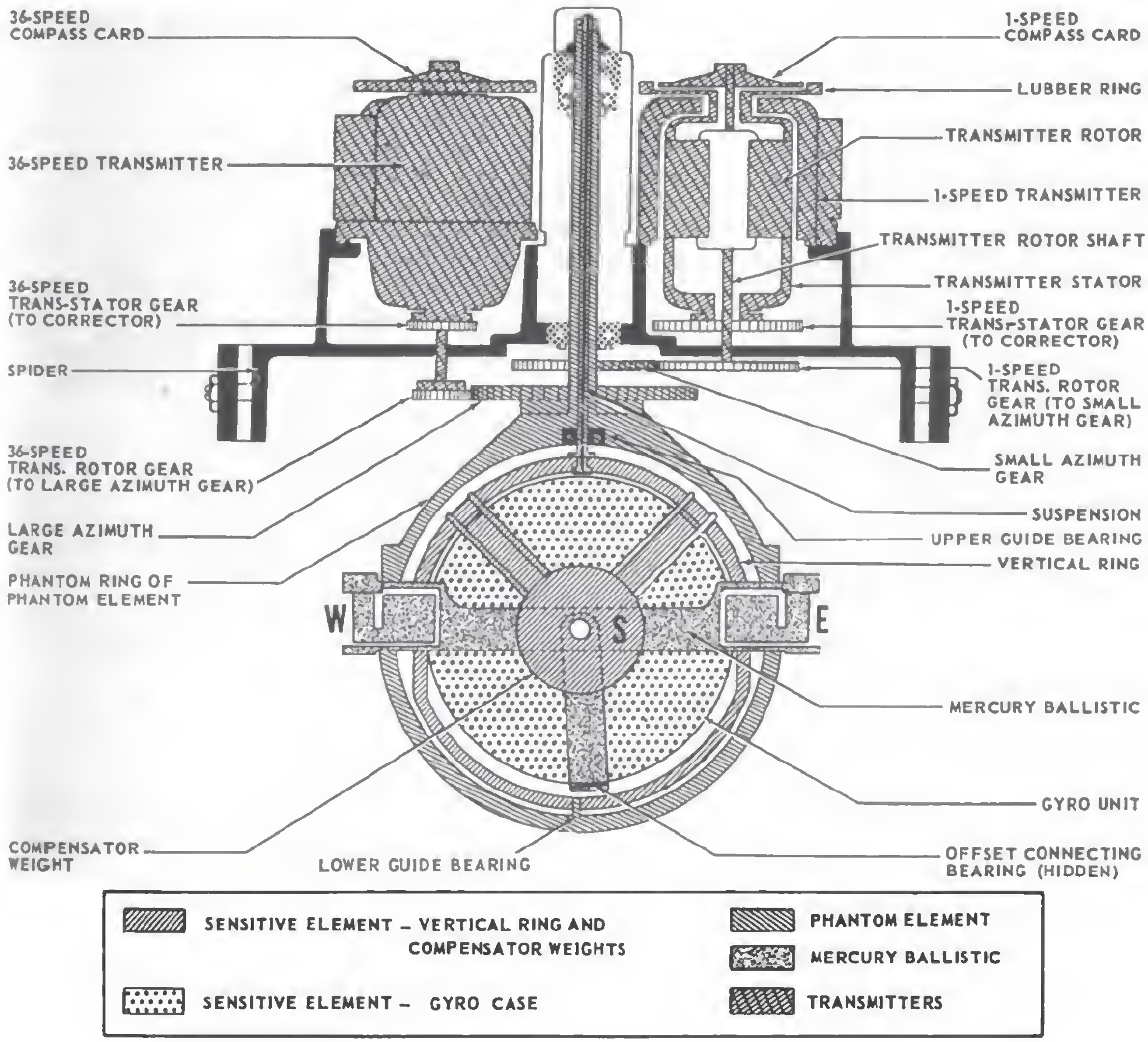

Figure 5-12.—South elevation of Sperry Mk XI Mod 6 Master Gyrocompass.

north-seeking. It consists of a rigid frame supported on bearings in the phantom ring. These bearings are in line with the horizontal case bearings, E, in the vertical ring so that the mercury ballistic is free to tilt about the east-west axis of the sensitive element (fig. 5-11).

The frame supports a mercury reservoir in each of its four corners. The N and S reservoirs on the east side of the compass are connected by a U-shaped tube and the N and S reservoirs on the west side are similarly connected. The gravity controlling force of the mercury ballistic is applied to the bottom of the gyro case through an adjustable offset bearing stud mounted on the ballistic connection arm (fig. 5-11).

The connection bearing is offset to the east from the vertical axis by a short distance to provide the damping adjustment. When it is desired to eliminate damping, a solenoid (damping

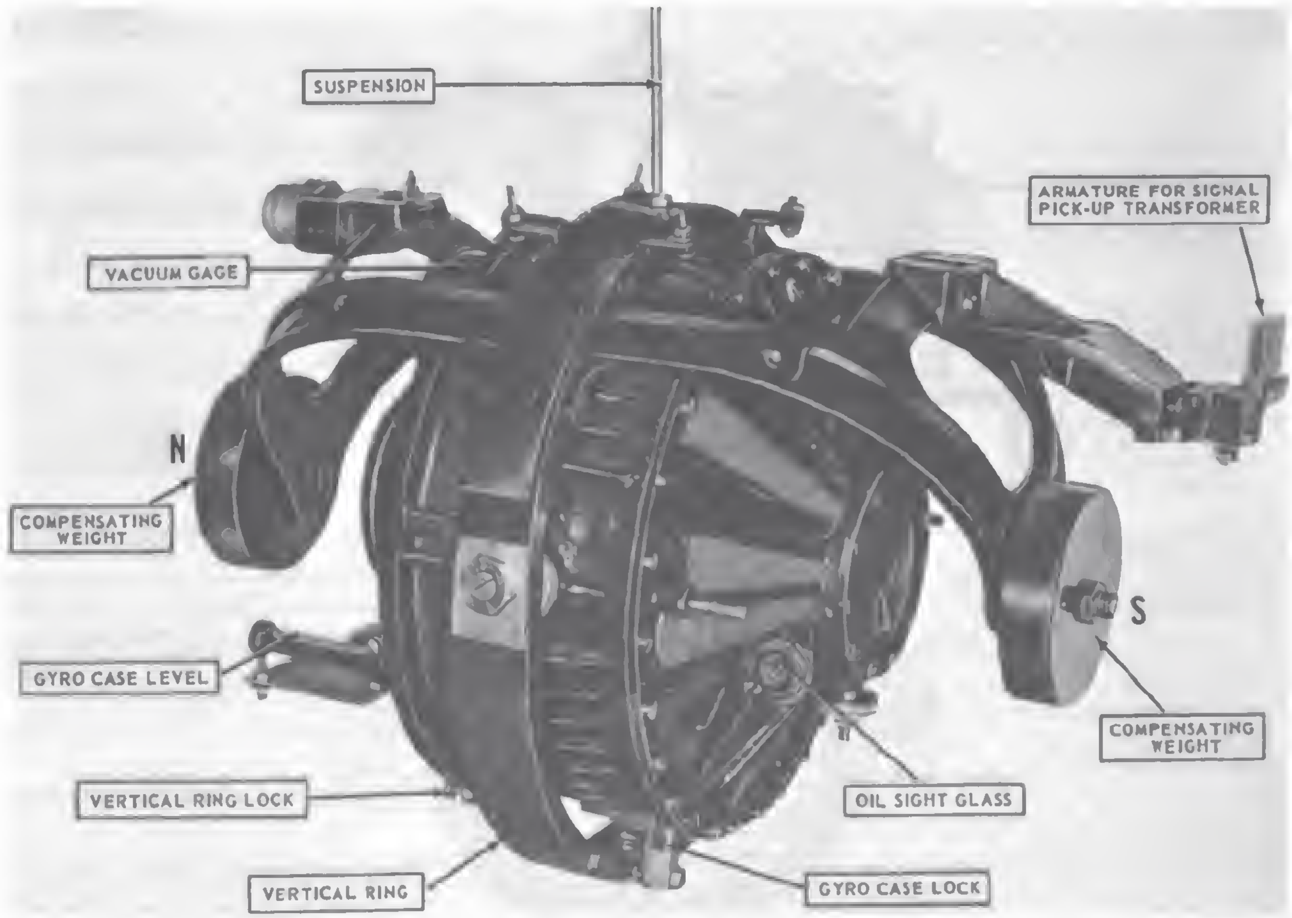

Figure 5-13.—Sperry Mk XI Mod 6 sensitive element.

eliminator magnet) is energized by an automatic damping eliminator switch (discussed later) that attracts a plunger which moves the pivoted connection arm until the connection bearing is in line with the vertical axis of the gyro. In addition, each mercury reservoir is offset from its supporting stem so that each can be rotated around its stem through an arc of about 110° in order to vary the lever arm of each tank. Thus the period of an undamped oscillation of the gyrocompass remains constant in all latitudes by adjustment of the mercury reservoir. This adjustment is referred to as the ballistic latitude adjustment. The reservoirs are arranged with worm wheels and a connecting shaft so that when the shaft is turned the reservoirs are rotated simultaneously closer to, or farther from, the horizontal centerline of the gyrocompass.

An engraved latitude scale is mounted on top of each mercury reservoir worm wheel. By setting the latitude scales to the local latitude and undamped compass period of 85 minutes is maintained at all latitudes thus eliminating any ballistic deflection error as discussed previously.

PHAMTOM ELEMENT

The phantom element (fig. 5-16) is a group of parts that acts to support the sensitive element. It consists essentially of a hollow cylindrical stem that projects radially from the

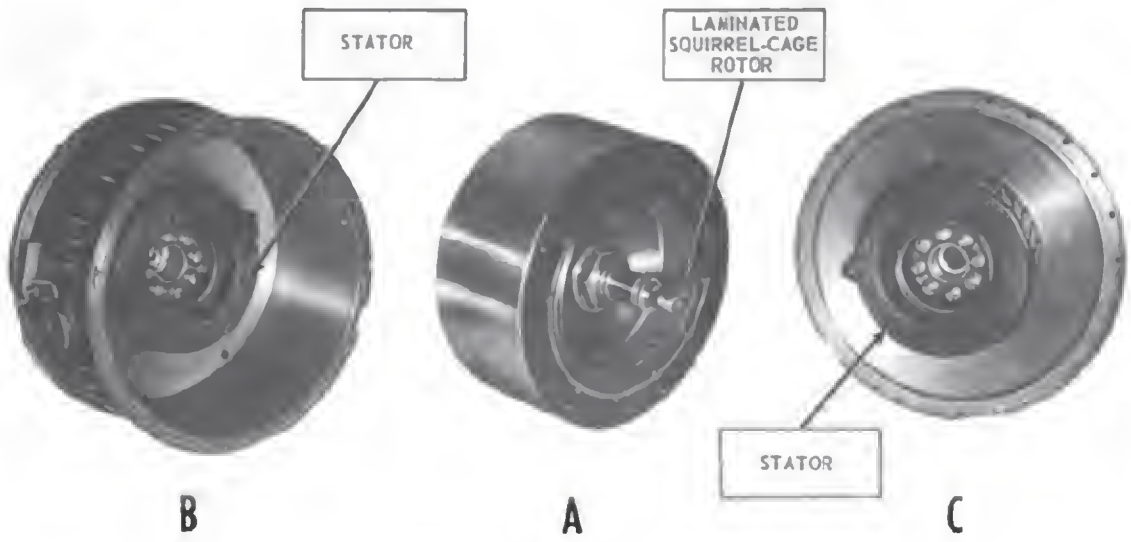

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Figure 5-14.—Sperry Mk XI Mod 6 gyro unit. A. Rotor; B and C, case.

phantom ring, which is mounted in the spider and extends below the central hub of the spider table.

The phantom element supports the sensitive element by means of the suspension (fig. 5-12). It has no north seeking properties of its own, however, it does continuously indicate north, because it is made to follow all movements of the sensitive element by the action of the followup system (described later).

A thrust bearing on the top of the stem (fig. 5-16) rests in the hub of the spider table and supports the weight of the phantom and sensitive elements. The upper and lower stem bearings keep the stem in alignment with the vertical axis of the spider but permit the phantom element to rotate about its own vertical axis.

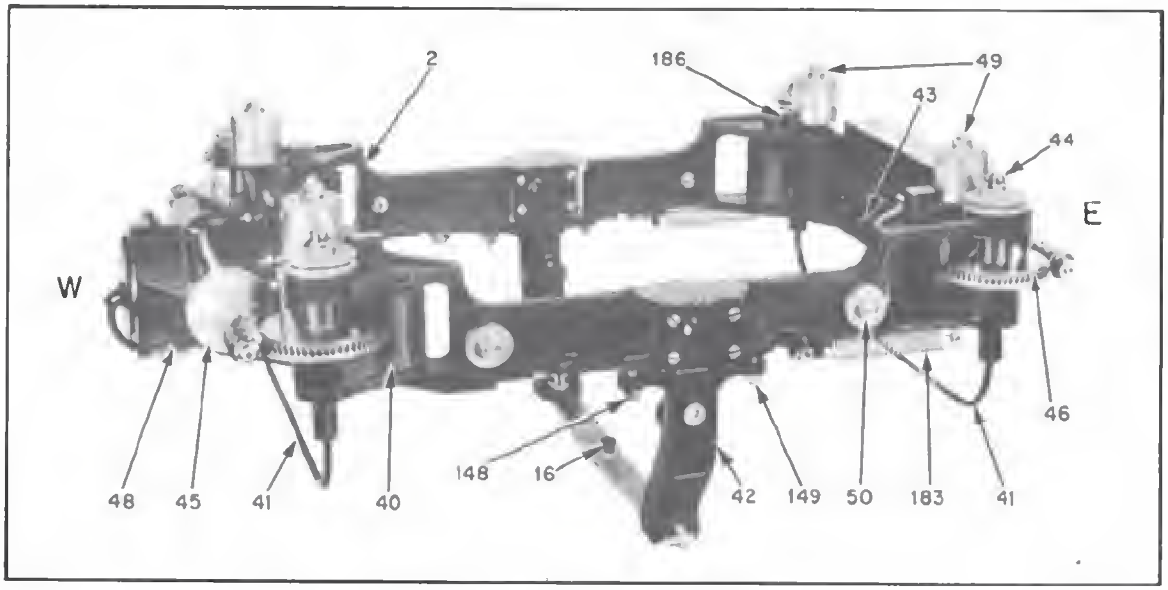
The phantom ring also carries bearings that support the mercury ballistic. The axis of these bearings coincides with the axis of the horizontal bearings of the gyro case. Collector rings are mounted on the phantom stem below the upper stem bearing to connect the various electrical circuits from the fixed to the moving parts of the compass. The large and small azimuth gears are included in the azimuth followup mechanism (to be discussed later).

An eccentric groove called the cosine cam is cut into the upper surface of the large azimuth gear. The cosine cam is associated with the speed and latitude corrector as previously discussed.

SPIDER

The spider (fig. 5-17) is a circular table of cast aluminum alloy that supports the entire inner, or moving, member of the compass by means of the hub on which the thrust bearing that supports the phantom element rests. The spider is supported in the inner, or cardan, ring of the two rings that comprise the gimball system. A boss in the center of the table supports the thrust bearing and the upper and lower stem bearings.

The azimuth followup motor (fig. 5-11) and the automatic damping eliminator switch are mounted on the forward side of the spider table. The speed and latitude correction mechanism and the auxiliary latitude corrector are mounted on the after side of the table. The 36-speed synchro transmitter (fig. 5-12) is located on the port side and the 1-speed synchro transmitter is located on the starboard side of the table.



2 MERCURY BALLISTIC FRAME	46 LATITUDE SCALE
16 OFFSET CONNECTION BEARING STUD	48 DAMPING ELIMINATOR MAGNET
40 MERCURY RESERVOIRS	49 NON-PENDULOUS BALANCING WEIGHTS
41 MERCURY TUBE	50 HORIZONTAL BALANCING WEIGHTS
42 CONNECTION ARM	148 NO-DAMPING ADJUSTMENT SCREW
43 MERCURY BALLISTIC SUPPORT STUD	149 DAMPING ADJUSTMENT
44 MERCURY RESERVOIR SUPPORT STEM	183 MAGNET LINK SPRING
45 LATITUDE SETTING THUMB WHEEL	186 LEVELING SCREW HOLES

40.32

Figure 5-15.—Sperry Mk XI Mod 6 mercury ballistic.

BINNACLE AND GIMBAL RINGS

The binnacle and gimbal rings (fig.5-18) enclose and support the entire master compass. The compass is suspended in the binnacle by means of a system of gimbal rings. The spider is supported on the inner, or cardan ring by ball bearings on the athwartships trunnions. This arrangement allows the compass to swing fore and aft in the binnacle.

The cardan ring is supported in the outer gimbal ring by fore-and-aft studs and bearings. This arrangement allows the compass to swing from side to side. The outer gimbal ring is suspended from the binnacle by a number of coil springs. This spring suspension helps to absorb any sudden shock to which the compass might be subjected.

The combination of the inner and the outer gimbal rings allows the compass to make any fore-and-aft and athwartship movements with respect to the binnacle and permits the compass to hang in a vertical position during rolling and pitching of the ship.

The gimbal rings are provided with roll dampers and pitch dampers to prevent violent swinging of the compass in rough weather. The ROLL DAMPERS are located in the binnacle on the forward side to reduce any swinging of the compass in its gimbals about the fore-and-aft axis when the ship is rolling. The PITCH DAMPERS are located on the port and starboard pivots of the spider to reduce any swinging of the compass in its gimbals about the athwartship axis when the ship is pitching.

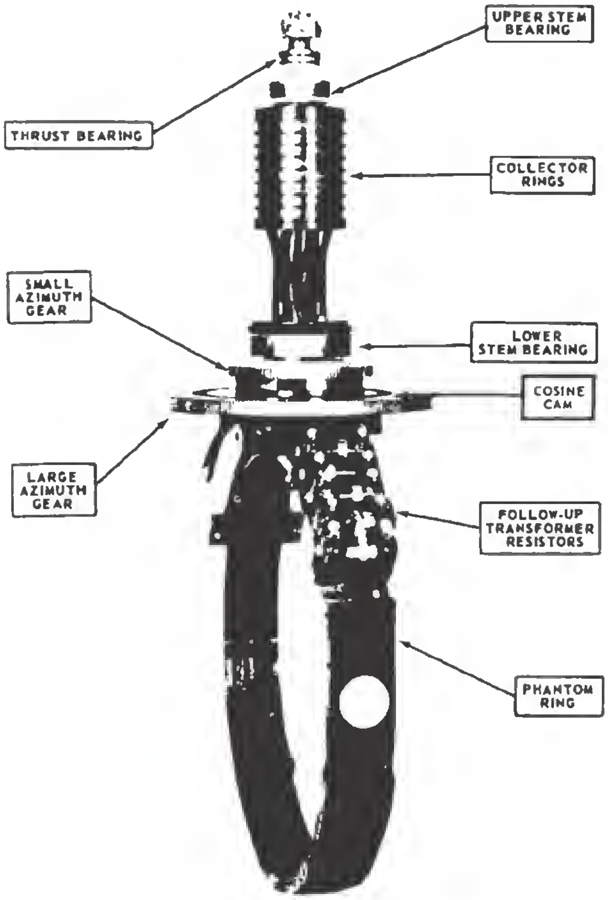


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Figure 5-16.—Sperry Mk XI Mod 6 phantom element.

The roll dampers comprise a twin dashpot assembly secured to the inner side of the outer gimbal ring. One plunger of this assembly extends upward on the port side of the forward trunnion bearing. Each dashpot contains a piston and a quantity of oil. When the roll exceeds a certain minimum, two studs mounted on the cardan ring are alternately brought to bear against the pistons. This action forces the oil through a small opening that resists the flow of oil and restricts the movement of the pistons, thereby restricting the swinging of the compass.

The pitch dampers comprise a set of friction dampers secured to the cardan ring. These dampers operate on eccentric friction disks attached to the spider.

The binnacle consists of a circular sheet steel body bolted on a cast-aluminum base. The binnacle base is secured to a round steel mounting plate that is bolted to the deck in such a position that the compass parts, supended within the cardan ring, swing about the athwartship axis which remains horizontal. The steel mounting plate is provided with elongated holes to allow for a $\pm 5^{\circ}$ rotational movement of the binnacle to adjust the compass relative to the fore-and-aft axis of the ship.

The body is provided with two pairs of doors and a cover. Each door is hinged to the body. One door of each pair can be secured in the closed positon by a latch and the other door locked to it. When the doors are open they can be lifted off their hinges and removed.

The cover consists of a sheet metal spinning provided with a flat glass top through which the compass card and lubber's ring can be observed. The cover is provided with two sets of double-hinged covers both of which can be locked with the same key. A metal protective cover is provided to protect the glass top when the compass is not in use.

CONTROL SYSTEM

The Sperry Mk XI Mod 6 gyrocompass control and alarm system consists of a motor-generator, speed regulator, control panel, battery throwover panel, and bridge alarm indicator, with the necessary apparatus for the operation and control of the master compass. The principal components of the control system are illustrated in figure 5-19.

The gyrocompass drive system consists of the primary and emergency sources of power. The primary power source is the ship's 3-phase, 120-volt, 60-cycle supply, and the emergency power source is the 24-volt battery supply as illustrated in the schematic wiring diagram of figure 5-20.

Motor-Generator

Two separate motor-generator sets are provided with each complete Sperry gyrocompass equipment. Each set consists of an induction

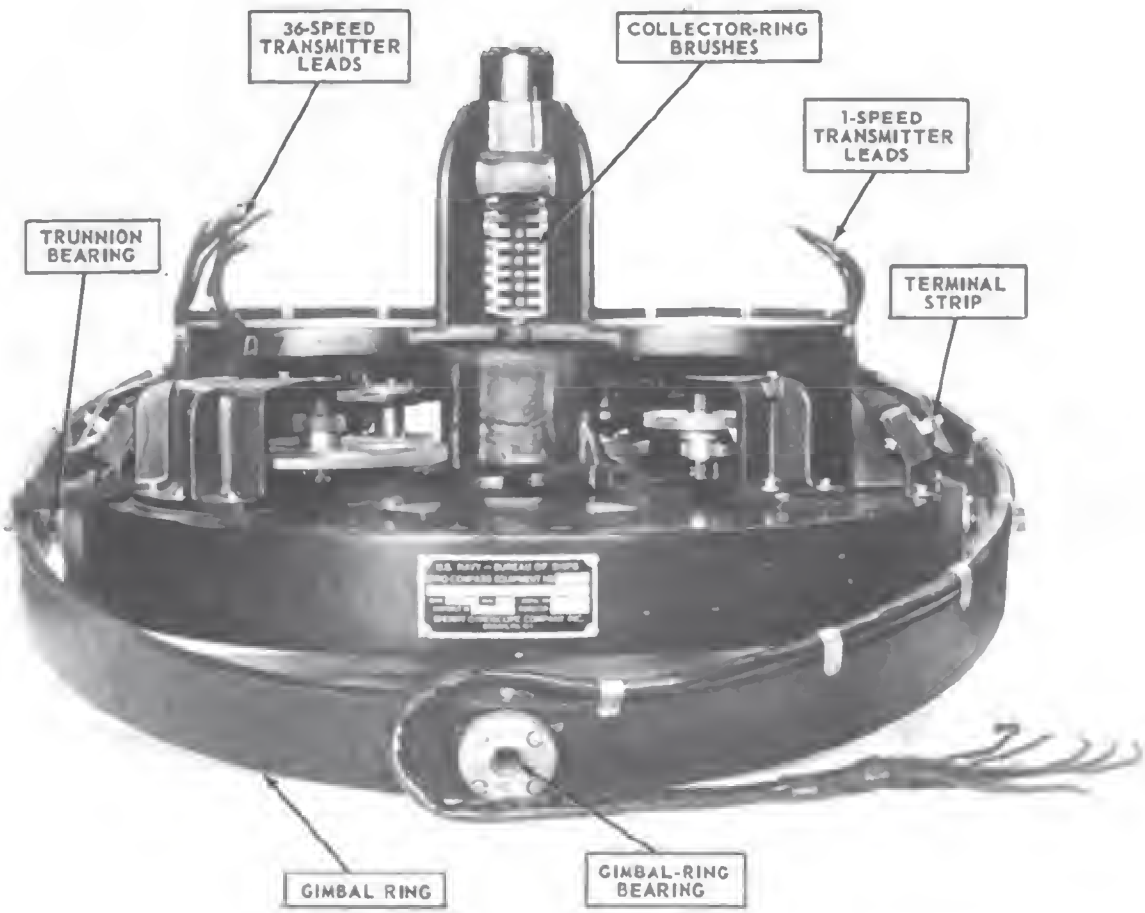

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Figure 5-17.—Sperry Mk XI Mod 6 spider element.

motor, a d-c emergency motor, an a-c generator, and a d-c generator (fig. 5-20). The induction motor and the d-c emergency motor are mounted on a common shaft in a single frame. The a-c generator and the d-c generator are also mounted on a common shaft in a single frame. The shafts of these two units are directly coupled together. Each motor-generator set is assembled as a complete unit and mounted on a single bedplate.

The induction motor is a 3-phase, 120-volt, 60-cycle, WOUND-ROTOR motor with slip rings. Under normal operating conditions, the induction motor drives the d-c motor, the a-c generator, and the d-c generator. It operates at a constant speed of 1460 rpm (necessary for the a-c generator to deliver a constant 3-phase output of 55 volts at 195 cycles), which is maintained constant by means of a speed regulator that compensates for a maximum of ±10% variations in the ship's primary power supply frequency.

The D-C MOTOR is a shunt-wound machine. Under normal conditions of induction motor drive, the d-c motor operates as a self-excited d-c generator for charging the battery with a continuous-duty rating of 21 volts at 7 amperes.

Under emergency operating conditions because of failure in the ship's 3-phase supply to the induction motor, the d-c motor operates from the battery supply to drive the a-c and

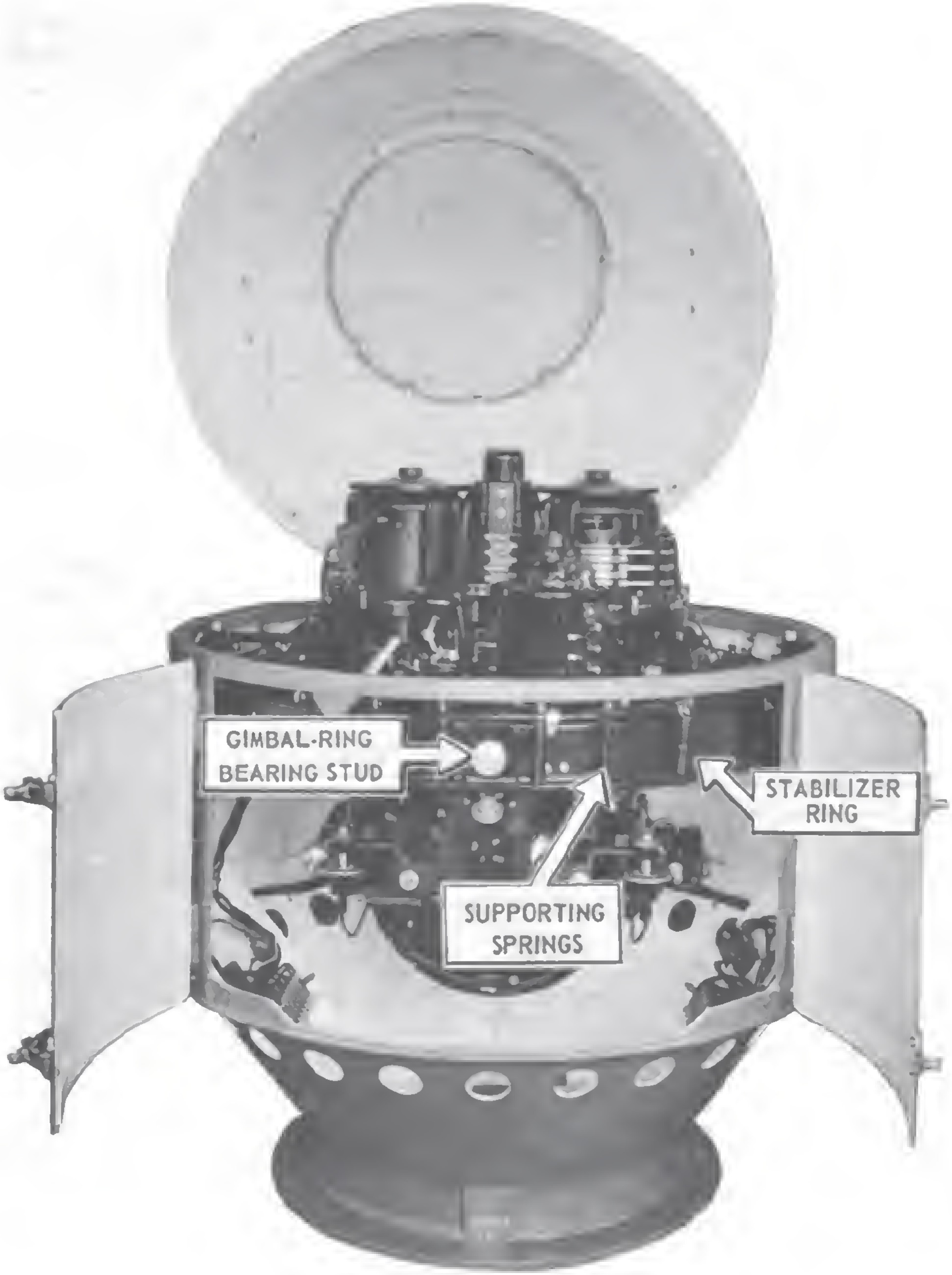

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Figure 5-18.—Sperry Mk 11 Mod 6 gyrocompass, showing binnacle and gimbal rings.

d-c generators. As a d-c motor, it has an intermittent-duty rating of 22.5 volts at 70 amperes.

The A-C GENERATOR is a 3-phase, 60-volt, 195-cycle inductor-type generator having 16 polar projections. Both the field and the armature are stationary. The 16 polar projections (inductors) rotate continuously at approximately 1,460 rpm, thereby varying the magnetic field flux through the armature windings and

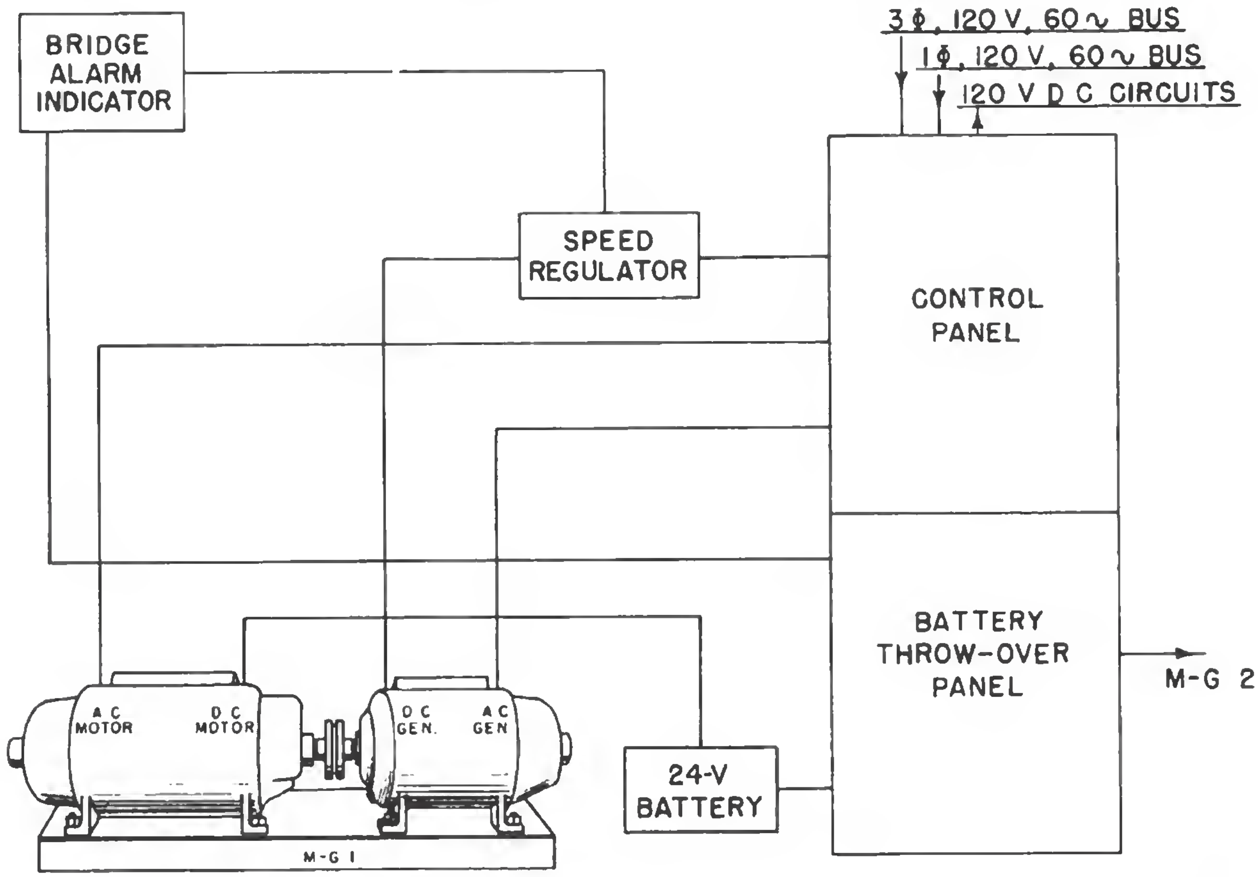

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Figure 5-19.—Sperry Mk 11 Mod 6 gyrcompass control and alarm system.

generating a-c voltage at a frequency of 195 cps. The armature consists of a wye-connected, 3-phase winding and the field consists of a single d-c winding. Slip rings are not required with this type of generator. This machine supplies power to drive the gyro rotor and to energize the amplifier and the followup system.

The D-C GENERATOR is a 120-volt, compound-wound, interpole, self-excited generator. This machine supplies excitation for its own fields, the a-c generator field, and the azimuth motor field. It also supplies d-c power for the damping eliminator, the azimuth-motor cutout relay, the dead reckoning equipment (DRE), and the voltage coil of the speed regulator.

Speed Regulator

The speed regulator (fig. 5-20) is a separate unit located adjacent to the motor-generator sets. It compensates for variations in the ship's supply voltage or frequency to maintain the speed of the induction motor constant and thereby causes the a-c generator to deliver a constant output to drive the gyro motor. The same speed regulator is used for each of the two motor-generator sets because they are not operated simultaneously.

The speed regulator consists of a wye-connected, carbon-pile voltage regulator connected in the form-wound rotor circuit of the 3-phase induction motor by means of slip rings.

The actuating coil of the speed regulator is connected in a shunt circuit across the output terminals of the d-c generator. It therefore responds to changes in d-c output voltage occasioned by any changes in speed of the motor generator. The voltage coil, VC, attracts a spring-loaded pressure arm that varies the pressure on the carbon piles in accordance with any change in voltage across the coil.

If the ship's supply voltage or frequency increases, the induction motor-rotor currents

increases. This action causes a slight increase in the speed of the motor-generator. The consequent slight increase in d-c generator voltage causes the voltage coil and the speed regulator to attract the spring-loaded arm. This action decreases the pressure on the carbon piles. The accompanying increase in rotor-circuit resistance restores the rotor currents to their normal value and checks the rise in speed and d-c generator output voltage.

A dashpot damper is connected to the pressure arm to prevent hunting when rapid changes occur in the voltage or frequency.

A holding-coil contact on the speed regulator is in series with the holding coil of the battery throwover relay (on the battery throwover panel). This contact is operated by the pressure arm and at reduced speed opens the relay to cut in the battery supply.

If the regulated speed changes with heavy loads, and the fault is not in the connections or in the generator, the difficulty may be due to lack of pressure on the carbon piles. The initial adjustment of the pressure on the carbon piles is by means of the large knurled nut located on the left-hand side of the regulator (fig. 5-21). This knurled nut extends through the left-hand bracket and bears against a hinged plate that, in turn, bears against the carbon piles. This nut can be screwed IN or OUT on the stud, D, to increase or decrease the pressure of the hinged plate on the carbon piles simultaneously. This adjustment also regulates the range that the armature can swing between the inside and outside armature stops. The more the pressure on the piles the smaller will be the range of swing of the armature.

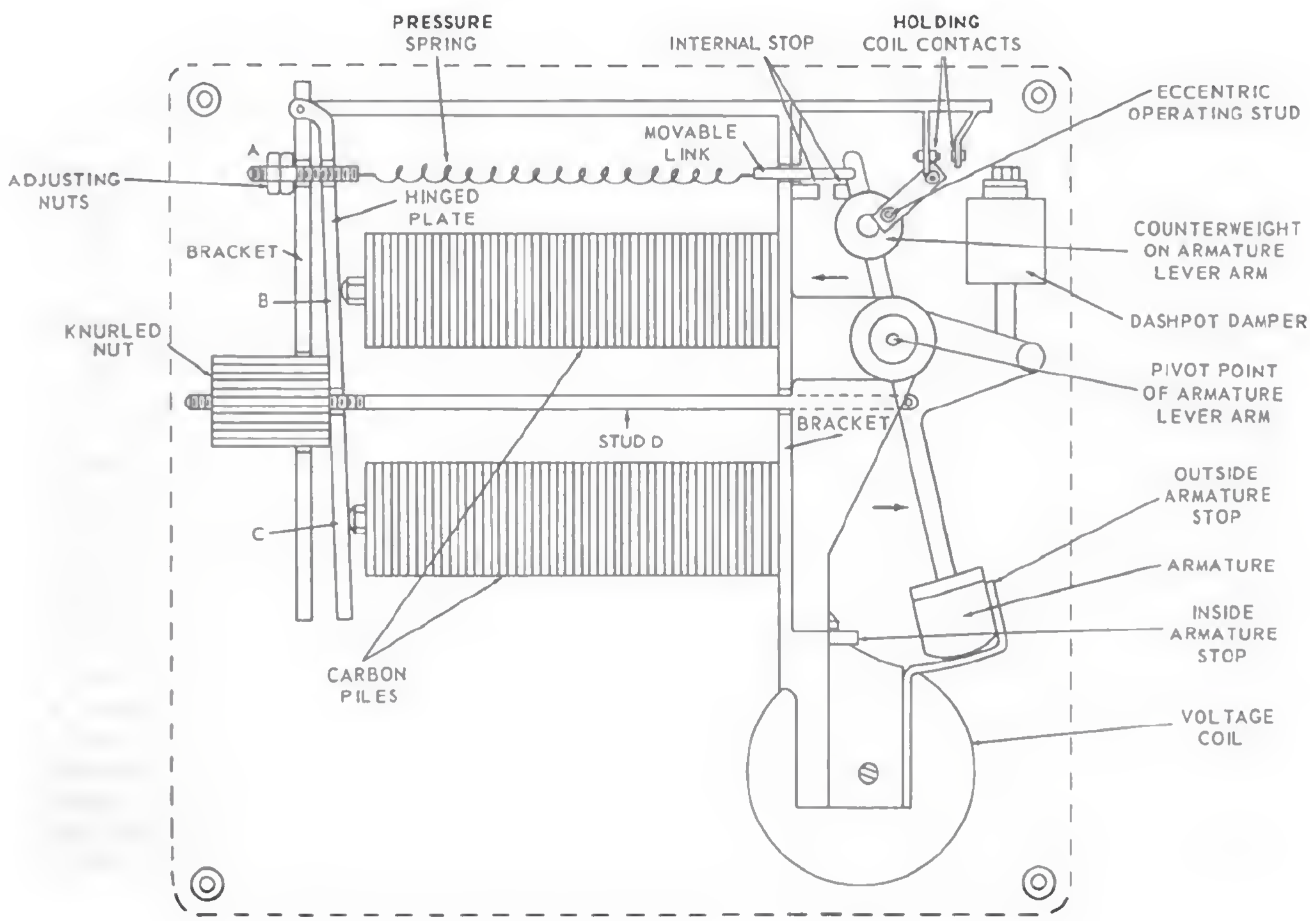

Figure 5-21.—Speed regulator schematic.

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increases. This action causes a slight increase in the speed of the motor-generator. The consequent slight increase in d-c generator voltage causes the voltage coil and the speed regulator to attract the spring-loaded arm. This action decreases the pressure on the carbon piles. The accompanying increase in rotor-circuit resistance restores the rotor currents to their normal value and checks the rise in speed and d-c generator output voltage.

A dashpot damper is connected to the pressure arm to prevent hunting when rapid changes occur in the voltage or frequency.

A holding-coil contact on the speed regulator is in series with the holding coil of the battery throwover relay (on the battery throwover panel). This contact is operated by the pressure arm and at reduced speed opens the relay to cut in the battery supply.

If the regulated speed changes with heavy loads, and the fault is not in the connections or in the generator, the difficulty may be due to lack of pressure on the carbon piles. The initial adjustment of the pressure on the carbon piles is by means of the large knurled nut located on the left-hand side of the regulator (fig. 5-21). This knurled nut extends through the left-hand bracket and bears against a hinged plate that, in turn, bears against the carbon piles. This nut can be screwed IN or OUT on the stud, D, to increase or decrease the pressure of the hinged plate on the carbon piles simultaneously. This adjustment also regulates the range that the armature can swing between the inside and outside armature stops. The more the pressure on the piles the smaller will be the range of swing of the armature.

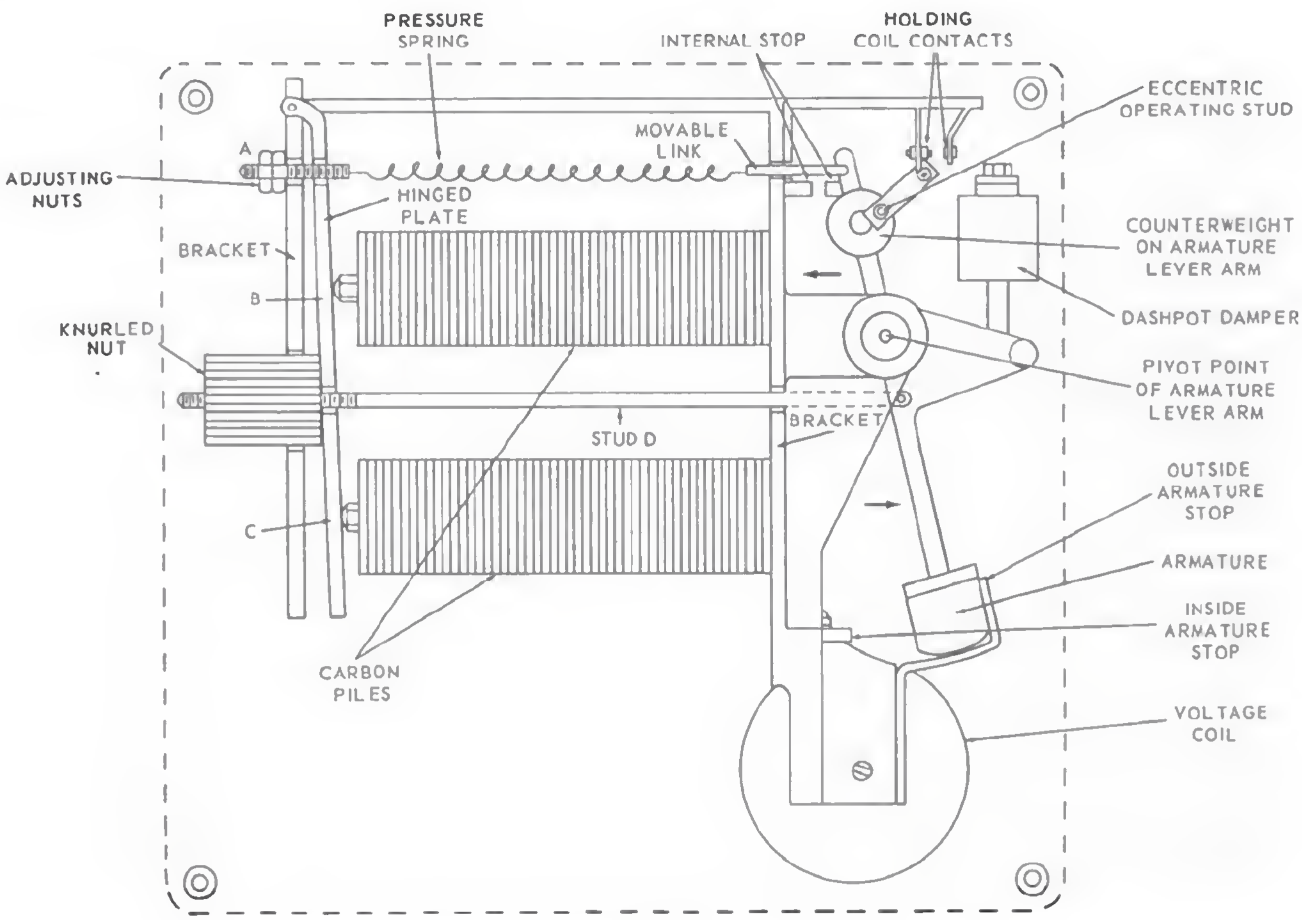

Figure 5-21.—Speed regulator schematic.

The pressure on the carbons is adjusted with the voltage coil deenergized and with the outside armature stop removed. The armature is pulled down against the spring tension of the two adjusting nuts (located above the knurled nut), which decreases the pressure on the carbon piles. The knurled adjusting nut is screwed IN until the armature lever arm barely makes contact with the internal armature stop when the armature is released. The internal armature stop consists of a stationary stop and a movable stop. The stationary stop is secured to the right-hand bracket that supports the armature and voltage coil assembly. The movable stop is attached to the armature lever arm adjacent to the counterweight. The knurled nut is now loosened one-half turn to allow the movable stop to go back freely against the stationary stop. The outside armature stop is now replaced. Never try to change the speed setting by adjusting the knurled nut, as this adjustment results only in reducing the range of the regulator.

The operating speed of the motor-generator can be regulated by means of the two adjusting nuts at point A, mounted on a stud that protrudes through the left-hand bracket (fig. 5-21). The stud is attached to one end of a tension spring. The other end of this spring is attached to a movable link that is secured to the armature lever arm above the pivot point. The movable link protrudes through a bracket on the right-hand side of the regulator.

To increase speed, the adjusting nuts (one nut serves only as a lock nut) are screwed further IN on the stud. This action increases the spring tension at point A, which (1) increases the pull against the armature lever arm, and (2) increases the pressure applied to the carbon piles at points B and C through stud D. This action increases the spring pressure on the carbon piles and decreases the resistance in the rotor circuit of the induction motor, thereby increasing the regulated speed of the motor-generator. Conversely, to reduce speed, the adjusting nuts are screwed farther OUT on the stud, which reduces the spring pressure on the carbon piles and increases the resistance, thereby reducing the regulated speed.

The dashpot is of the inverted air type provided with a graphite plunger and air-vent adjustment. This vent is adjusted so as to barely overcome any tendency of the regulator to hunt when the load is light or when starting up. Care should be taken not to close the vent too much because this will reduce the sensitivity of the regulator. The dashpot action is continuous regardless of temperature changes.

When the a-c supply drops to approximately 80 volts and/or 54-cycles, the carbon pile pressure arm automatically open the holding coil contacts on the speed regulator. The adjustment of these contacts are then made by supplying the induction motor of the motor-generator with 54-cycle, 3-phase power at about 103 volts. With this supply the holding coil contacts barely open. If they do not open, loosen the nut holding the eccentric operating stud on the contact operating arm and turn the stud with a wrench until the contacts open. If further adjustment is required, remove the contact base cover (not shown in the figure). Loosen the contact holding screws (holding either the fixed or movable contact), and adjust the contacts to either increase or decrease the gap as desired.

Compass Control Panel

The compass control panel is located at the upper left-hand section of the gyrocompass switchboard (fig. 5-22). The control panel is used to control and indicate the operating conditions to the master compass. The ship's 3-phase, 120-volt, 60-cycle power supply are connected directly to terminals on the back of the compass control panel. The 3-phase, 120-volt, 60-cycle power supply is fed from these terminals on the control panel through the battery throwover relay on the battery throwover panel to the motor-generator transfer switch on the compass control panel. The switches and fuses necessary for these power supplies are included on the I. C. switchboards and are not provided on the gyrocompass switchboard.

The a-c ammeters and an a-c voltmeter are mounted at the top of the control panel to indicate the operating conditions of the master compass. One ammeter indicates the 60-cycle alternating current supplied to the synchro repeater system by the master compass transmitter, and the other ammeter and the voltmeter indicate the 195-cycle current and voltage respectively supplied by the 3-phase, a-c generator to the gyrocompass rotor.

The azimuth-motor cutout detent release, the 1-speed and 36-speed overload signal lamps, and the volt-ammeter selector switch are mounted just below the two ammeters and the voltmeter.

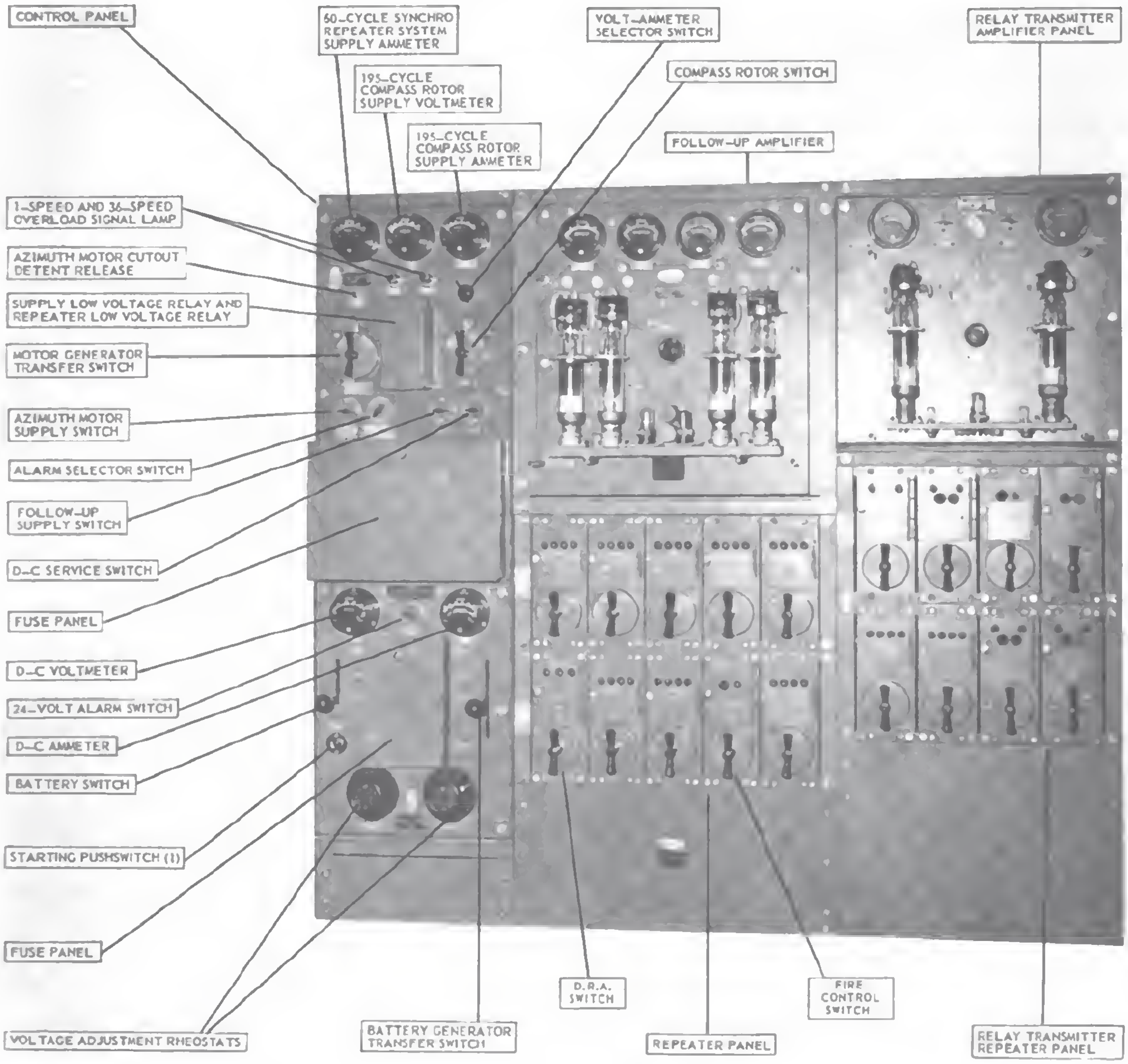

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Figure 5-22.—Sperry Mk 11 Mod 6 gyrocompass switchboard.

The azimuth motor cutout detent release is provided to reset the cutout after a fault has been cleared on the followup system.

The volt-ammeter selector switch is a 3-position rotary switch. The three switch positions provide for shifting the ammeter and voltmeter to any of three phases of the a-c gyro rotor supply obtain current and voltage readings of the selected phase.

The motor-generator transfer switch, the supply low-voltage relay, the repeater low-voltage relay, and the compass rotor switch are mounted on the third row from the top.

The motor-generator transfer switch (fig. 5-20) is a double-throw rotary switch provided for selecting either one or the other of the two motor-generators.

The ship's supply low-voltage alarm relay ① consists of a shunt coil connected across one phase of the ship's 3-phase supply. The coil holds the relay armature against the front contacts as long as this supply is available. If this supply fails, the armature drops and closes the back contacts to sound the alarm bell.

The repeater low-voltage relay ② is similar to the supply low-voltage relay. If the ship's single-phase supply to the repeaters fails, this relay operates to sound the alarm bell.

The compass rotor switch connects the 3-phase, 55-volt, 195-cycle power from the a-c generator to the gyrocompass rotor.

The azimuth-motor switch, the alarm selector switch, the follow-up supply switch, and the d-c service switch are located at the bottom of the control panel.

The azimuth-motor switch controls the (1) rectified a-c supply circuit to the azimuth motor armature and (2) the d-c supply to the azimuth-motor field.

The alarm selector switch is a rotary switch with four positions marked (1) normal (2) low frequency, (3) repeater supply, and (4) ship's supply. In the NORMAL position, the alarm bell sounds if the ship's supply or the repeater supply fail or if the supply voltage or frequency fall below a predetermined value. The alarm bell is silenced by turning the selector switch to the position indicating the trouble.

The followup supply switch is an on-off switch. In the ON position it energizes the followup panel from one phase of the 3-phase gyro supply, and heats the filaments of the amplifiers and rectifier tubes in the followup system.

If the followup switch is in the OFF position, the compass supply ammeter and voltmeter indicate the current and voltage to the gyro rotor only; whereas, if this switch is in the ON position, the meters will indicate the 195-cycle current and voltage to both the gyro rotor and the followup panel.

The d-c service switch is the master switch for the 120-volt, d-c circuit. It supplies the (1) damping eliminator circuits, (2) azimuth-motor field, and (3) azimuth-motor cutout relay coil.

The fuses for the compass control panel are within an enclosure located at the bottom of this panel.

Battery Throwover Panel

The battery throwover panel is located directly below the compass control panel (fig. 5-22). It is used to transfer automatically the gyrocompass circuits from the ship's 3-phase supply to the battery supply in the event of failure of the ship's supply. The 24-volt storage battery is normally connected to the battery-charging generator of the motor-generator set and floats on the line.

If the ship's 3-phase supply voltage or frequency drops below the predetermined value (±10% of the normal value), the movement of the pressure arm on the carbon piles of the speed regulator will open the battery throwover relay holding coil contacts, thereby deenergizing this relay. When this relay is deenergized, the (1) ship's 3-phase supply is disconnected from the motor-generator set, (2) battery is connected to the d-c motor (charging generator) as a primary power source so that the d-c motor becomes the prime mover for the motor-generator set, and (3) alarm bell rings.

When the ship's 3-phase power supply is restored, retransfer of the drive to the induction motor must be accomplished manually.

The battery throwover panel components discussed in the following paragraphs are identified in the schematic wiring diagram (fig. 5-20).

A 24-volt alarm supply switch and a battery voltmeter and ammeter are mounted at the top of the battery throwover panel.

The 24-volt alarm supply switch is a separate switch provided for cutting out the supply to the entire alarm system.

The d-c ammeter and the d-c voltmeter connected between the battery switch and the battery-generator transfer switch, indicate the current and voltage respectively in the battery line.

The battery throwover relay is located on the back of the panel. This relay has six upper (main) contacts and one lower (interlocking) contact.

The battery throwover relay in figure 5-20 is shown in an energized condition. The upper contacts, 1 through 6, are read from left to right. All contacts (upper and lower), except the third are closed. When the holding coil deenergizes, the third contact is spring-closed and held. As shown, when energized, the first and second contacts connect two phases of the ship's 3-phase supply to the motor-generator

transfer switch on the compass control panel. The third and fourth contacts are alarm contacts; the third is open and the fourth is closed. The function of the alarm contacts is described in detail under:

ALARM SYSTEM OPERATION.—The fifth and sixth contacts shunt the series resistances in the field circuits of the two battery generators. The bottom contact is the interlocking contact and closes the circuit to the relay holding coil through the holding coil contacts on the speed regulator.

The fuses for the battery throwover panel are within an enclosure located in the center of the panel.

The battery switch and the battery-generator transfer switch are located on the left-hand and the right-hand sides of the fuse enclosure, respectively.

The battery switch is a DPST lever-angle switch that connects the 24-volt battery supply to the battery throwover panel.

The battery-generator transfer switch is a DPDT leverangle switch that connects the battery to one or the other of the two battery generators.

The starting pushswitch (1) is mounted below the battery switch. It is used to start the motor-generator and also to restore the circuit to the holding coil of the battery throwover relay after the system has been interrupted because of a failure of the ship's supply or low voltage and or frequency. When the relay closes, the circuit through the interlocking contact is restored and, if the ship's supply voltage and frequency are high enough to permit the holding coil contacts on the speed regulator panel to be closed, the relay will remain closed; otherwise the relay will drop open again when the pushswitch is released. Additional pushswitches in parallel with the starting pushswitch on the battery throwover panel are located on the bridge alarm units so that, if desired, the ship's power supply can be restored to the compass equipment from these stations.

Two voltage adjustment rheostats, one for each of the battery generators are mounted at the bottom of the panel. These rheostats are used to adjust the generator-field resistance to control the charging rate of the battery when the machine operates as a generator. The rheostats are cut out when the machine operates as a motor, and the resistance that is cut into the field by the battery throwover relay automatically increases the speed to the proper value.

Bridge Alarm Indicator

The bridge alarm indicator is located in the pilot house. The alarm circuits are included in figure 5-20. The indicator includes a red, a blue, and a green indicator lamp, a damping-eliminator pushswitch (3) and a starting pushswitch (2). These components are enclosed within a metal case provided for bulkhead mounting. An external alarm bell is located adjacent to this indicator.

The red indicator lamp in the battery supply indicates operation of the compass equipment from the 24-volt battery supply.

The blue indicator lamp is in the damping-eliminator circuit as a warning whenever the damping-eliminator coil is energized.

The green indicator lamp in the ship's a-c supply is lighted as long as the ship's supply is connected to the compass equipment.

Each indicator lamp is provided with a series variable resistor to control the intensity of illumination.

The starting pushswitch (2) in parallel with pushswitch (1) is provided to close the battery throwover relay and thus to connect the ship's supply to the compass equipment.

The damping-eliminator pushswitch (3) in parallel with the automatic damping-eliminator switch on the master compass may be manually operated to energize the damping-eliminator coil and thus remove damping when the ship makes a turn of more than 15° at a rate in excess of 40° per minute.

ALARM SYSTEM OPERATION

The alarm system is provided to indicate (1) throwover to emergency battery because of a reduction of more than 10 percent of the ship's supply frequency or voltage, or both, (2) failure of the ship's supply to the synchro repeaters, (3) failure of the ships 3-phase a-c supply, and (4) failure of the compass followup system.

The alarm system includes the ship's supply low-voltage alarm relay (1) (fig. 5-20) and the repeater low-voltage relay (2), previously described in connection with the compass control panel. It also includes the third and fourth contacts on the battery throwover relay, the alarm contact on the azimuth-motor cutout relay, the alarm supply switch on the battery throwover panel, the alarm selector switch on the compass control panel, the bridge alarm

indicators, and alarm bell. The primary power for this entire alarm circuit is the 24-bolt battery.

The alarm selector switch is used to locate the circuit in which trouble has occurred.

The bridge alarm indicators show when the compass is being driven by the emergency battery supply instead of the ship's supply, and also when the trouble has been cleared.

Drop in Frequency or Voltage

A drop in the frequency or voltage of the ship's supply of more than 10 percent of normal will cause the speed-regulator holding coil contacts to open (fig. 5-20). This action deenergizes the holding coil and opens the interlocking contact on the battery throwover relay and transfers the gyrocompass system to the 24-volt battery supply. At the same time, the alarm contacts on the battery throwover relay close and sound the alarm bell. The ringing circuit is from the negative side of the battery through the alarm supply switch to terminal 10 on the battery throwover panel and control panel, through the battery throwover relay contact 3 and through the LFA terminal on the alarm selector switch, to the positive (+) terminal of this switch. This circuit continues to terminal 11 on the control panel and battery throwover panel, through the alarm bell on the bridge indicator, through the alarm supply switch and back to the positive side of the battery, thereby completing the circuit and ringing the bell.

A second circuit is made when the battery throwover relay is opened. This circuit is from the LFA terminal on the battery throwover relay through the battery supply lamp (red) on the bridge alarm indicators, and back to the positive terminal of the battery to complete the circuit and light the red lamp.

Therefore, two signals are made when the battery throwover relay opens on low voltage or frequency, causing (1) the alarm bell to ring, and (2) the battery supply lamp to glow (red) on the bridge indicator, showing that the equipment has been transferred to the battery supply.

To silence the bell, the alarm selector switch is turned counterclockwise (clockwise in fig. 5-20) from the NORMAL position to the LOW FREQUENCY position. This breaks the ringing circuit at the LFA terminal on the alarm selector switch and makes a new circuit available at LFN on the selector switch (the circuit is open at the LFN contact on the battery throwover relay). When the bell stops ringing as the selector switch is turned, the indication is that the relay has opened because of low frequency or voltage.

When the selector switch is turned to the LOW FREQUENCY position, the bell will stop ringing but the red lamp remains lighted until the frequency returns to normal and the ship's supply is restored.

When the ship's supply returns to normal, the battery throwover relay will not reclose automatically because the lower interlocking contacts in the holding-coil circuit are open. The relay holding coil is energized only by manually operating starting pushswitch (1) on the battery throwover panel or pushswitch (2) on the bridge alarm unit. During battery operation, the battery throwover relay holding coil contacts are held in the closed position by the operating coil of the speed regulator. Thus when the pushswitch is operated, the lower interlocking contacts of the throwover relay will close as the coil energizes, and the relay locks in by its own contact.

When the ship's supply is restored, relay alarm contacts are made from terminal 10 through the battery throwover relay contact 4 to LFN on the alarm selector switch, through the switch to the positive terminal on this switch, through the alarm bell and back to the positive terminal of the battery to complete the circuit and ring the bell. To silence the bell, the selector switch is turned to NORMAL position, showing that the ship's supply has been restored.

Failure of Repeater Supply

When the alarm selector switch is in the NORMAL position and the repeater supply fails, the repeater-supply alarm relay (2) (fig. 5-20) opens the front contacts and closes the back contacts to sound the alarm bell. This circuit is from the negative terminal of the battery, through the alarm fuse and battery alarm switch, to terminal 10, to contacts on repeater supply alarm relay on the compass control panel, through back alarm contacts to RA, to RA on alarm selector switch, through the switch to the positive terminal, to terminal 11 on the battery throwover panel, through alarm bell fuse to 4LC11 on bridge alarm indicator, through the bell to terminal 4LC12 back through the

alarm battery switch and fuse, to the positive terminal of the battery. While the selector switch is at NORMAL position, the bell continues to ring, and a (red) battery lamp on the bridge indicator is lighted, to give a visual indication of trouble through the following circuit. This circuit is from RA on the repeater alarm relay to RA on the selector switch, to LFA on the selector switch, through the battery supply lamp fuse, through the battery lamp (red), to 4LC12, through the alarm supply switch to the positive terminal of the battery.

The alarm bell is silenced by turning the alarm selector switch from the NORMAL position to the REPEATER-SUPPLY position. This action opens the RA ringing circuit and the LFA circuit to the (red) battery lamp.

When the repeater supply is restored, the repeater supply alarm relay ② closes the front contacts and opens the back contacts to sound the alarm bell. This ringing circuit is from the negative terminal of the battery, through the alarm fuse and the alarm supply switch to terminal 10, through the front contacts of the repeater alarm relay ②, to RN to RN on the alarm selector switch, through the switch to the positive terminal on the switch, to terminal 11, through the alarm bell to 4LC12, through the alarm supply switch and fuse, and to the positive terminal of the battery. The bell rings, indicating that the repeater supply has been restored. To silence the bell, the alarm selector switch is turned to NORMAL.

Failure of Ship's Supply

If the ship's supply fails, the ship's supply alarm relay ① opens and thereby opens the front contacts and closes the back contacts, completing a circuit through the contacts SA to the alarm bell. In addition, because failure of the ship's supply affects the speed regulator, the holding coil contacts of the battery throwover relay opens, thereby opening the battery throwover relay and completing a second circuit through LFA on the relay to the (red) battery supply lamp and the alarm bell on the bridge alarm indicator. Failure of this supply therefore rings the bell and lights the battery supply lamp (red) as previously described. The green lamp which indicates that the ship's supply is connected to the compass equipment goes out. To silence the alarm bell, the alarm selector switch is turned from NORMAL to SHIP'S SUPPLY. The battery supply lamp on the bridge indicator however, remains lighted.

When the ship's supply is restored, the green lamp lights and the ship's supply alarm relay ① closes, thereby opening the alarm back contacts and making contact on the front SN contacts. This action rings the alarm bell again through the SN and positive terminals of the alarm selector switch. The bell is not silenced by turning the alarm selector switch from the SHIP'S SUPPLY position to the NORMAL position because the battery throwover relay is still open, and the bell will ring through the LFA circuit. Operating the starting pushswitch (on the bridge alarm indicator, or on the battery throwover panel) closes the battery throwover relay to interrupt the LFA circuits, silence the bell, and extinguish the red lamp.

Failure of Followup System

If the followup system fails, the out of alignment contacts on the master compass closes and energizes the azimuth-motor cutout relay coil to close the alarm contacts and sound the alarm bell. This circuit is from the negative side of the battery, through the alarm fuse and alarm supply switch, to terminal 10, to the cutout relay on the azimuth motor, through the relay contacts to terminal 11, through alarm bell fuse and alarm bell, to 4LC10 and to the positive side of the battery. Trouble in this circuit should be corrected without delay because the selector switch does not control the circuit and cannot silence the bell. The red lamp will be lighted with the alarm switch on NORMAL position only. Once the trouble has been corrected, the alarm bell stops ringing and the red lamp goes out. If the alarm selector switch has been turned to any position other than normal, it must be returned to NORMAL. The (green) ship's supply lamp is always lighted when the ship's supply is connected to the gyrocompass equipment.

FOLLOWUP SYSTEM

The followup system includes the followup mechanism, the followup transformer, the azimuth motor, and the followup panel. The system functions to detect any misalignment between the phantom and sensitive elements and to drive the phantom element in the proper direction to restore alignment. Any misalignment between the phantom and sensitive elements results in a signal voltage output from the followup transformer. The amount of misalignment determines the magnitude of this signal voltage and the direction of misalignment determines its phase.

The signal output from the followup transformer is amplified by a voltage amplifier and used to control the output of a power amplifier which operates the azimuth followup motor. The followup motor is driving the phantom element back into alignment with the sensitive element also drives the 1 and 36-speed synchro transmitters, and a lost motion device through the azimuth followup gearing mechanism (fig. 5-23).

The followup motor is a d-c motor having its field excited from the 120 volt d-c output from the motor generator. Its armature is connected in either one or the other of the two output rectifier circuits of the power amplifier. The direction of rotation depends upon which pair of output rectifiers is conducting when the plates of the voltage amplfiers are positive.

Followup Panel

The followup panel (fig. 5-22) is located adjacent to the compass control panel. It includes a voltage amplifier and a power amplifier.

The Voltage Amplifier consists of two twin triodes V1 and V2 (fig. 5-24). The signal voltage from the followup transformer is fed through

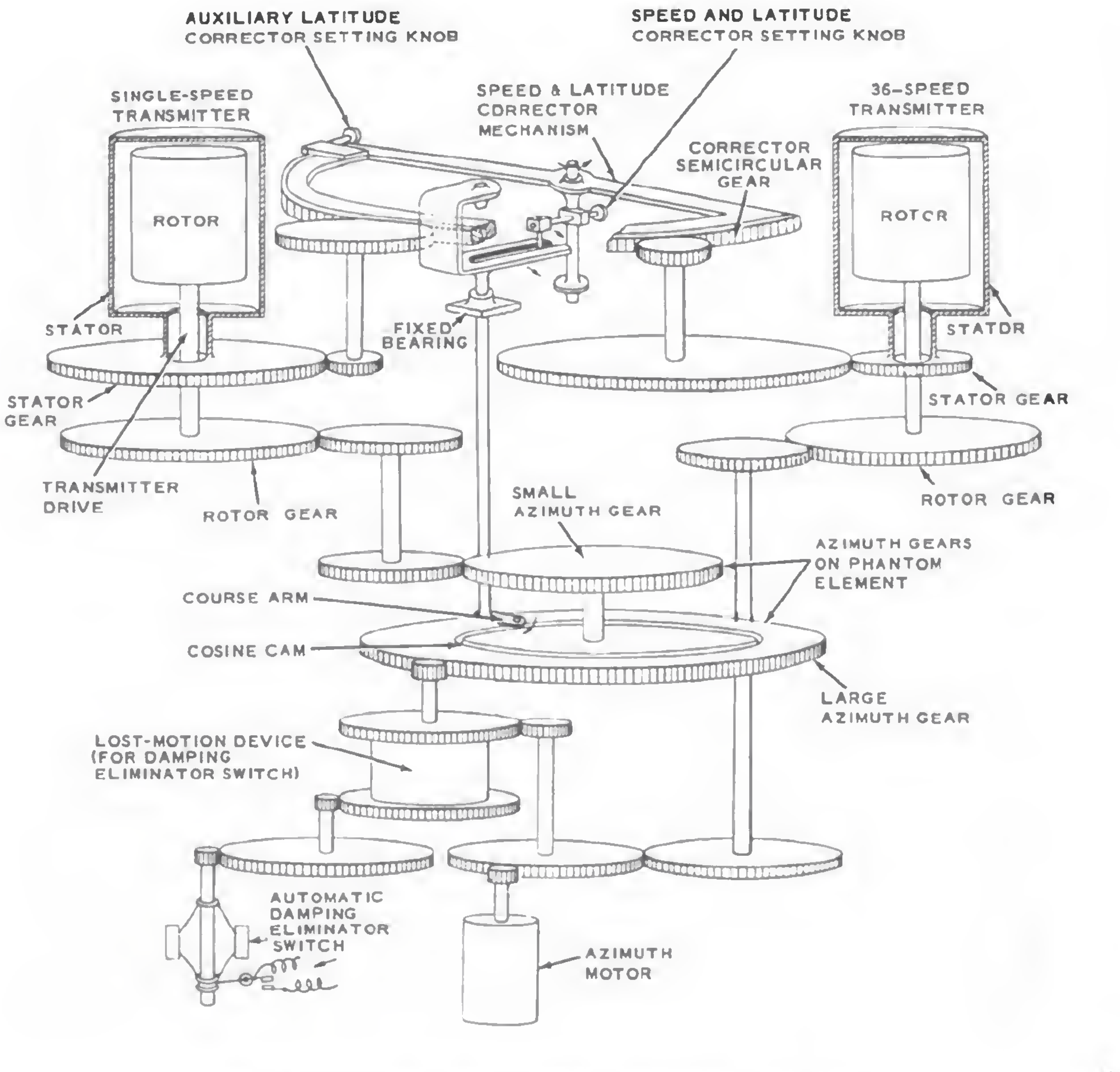


Figure 5-23.—Azimuth followup mechanism gearing.

slip rings to the input transformer, T2, the two primaries of which are in parallel. The magnitude of this signal is controlled by the potentiometer, P1.

The power amplifier consists of two pairs of thyratrons, GR1-GR2 and GR3-GR4 (fig. 5-24). The two thyratrons in a pair are paralleled in order to ensure continuous operation of the followup circuit in the event of tube failure. The thyratrons are grid-controlled rectifiers that produce a half-wave output.

When the ship turns, moving the phantom element away from the sensitive element, a signal voltage is induced in the followup transformer. This signal is amplified in the voltage amplifier and fed to the power amplifier, the output of which supplies the azimuth motor armature with half-wave pulses of voltage and current. The azimuth motor drives the phantom element back until it is alined with the sensitive element at which point the signal voltage becomes zero. In actual operation, the phantom element never becomes more than slightly displaced from the sensitive element because of the sensitivity of the followup control.

Followup Transformer

The followup transformer mounted on the phantom element (fig. 5-24) comprises 3 coils mounted on an E-shaped laminated core. The primary coil (1) mounted on the center leg is connected to the 3-phase, 195-cycle compass rotor supply through a resistor that limits the current to a few milliamperes. Note that one primary lead connects directly to one of the three phases; whereas the other lead ties to the common connection of two resistors bridged across the remaining two phases. This arrangement provides the proper phase relation between the input signal voltage and the bias and plate voltages of the gyrocompass followup circuits.

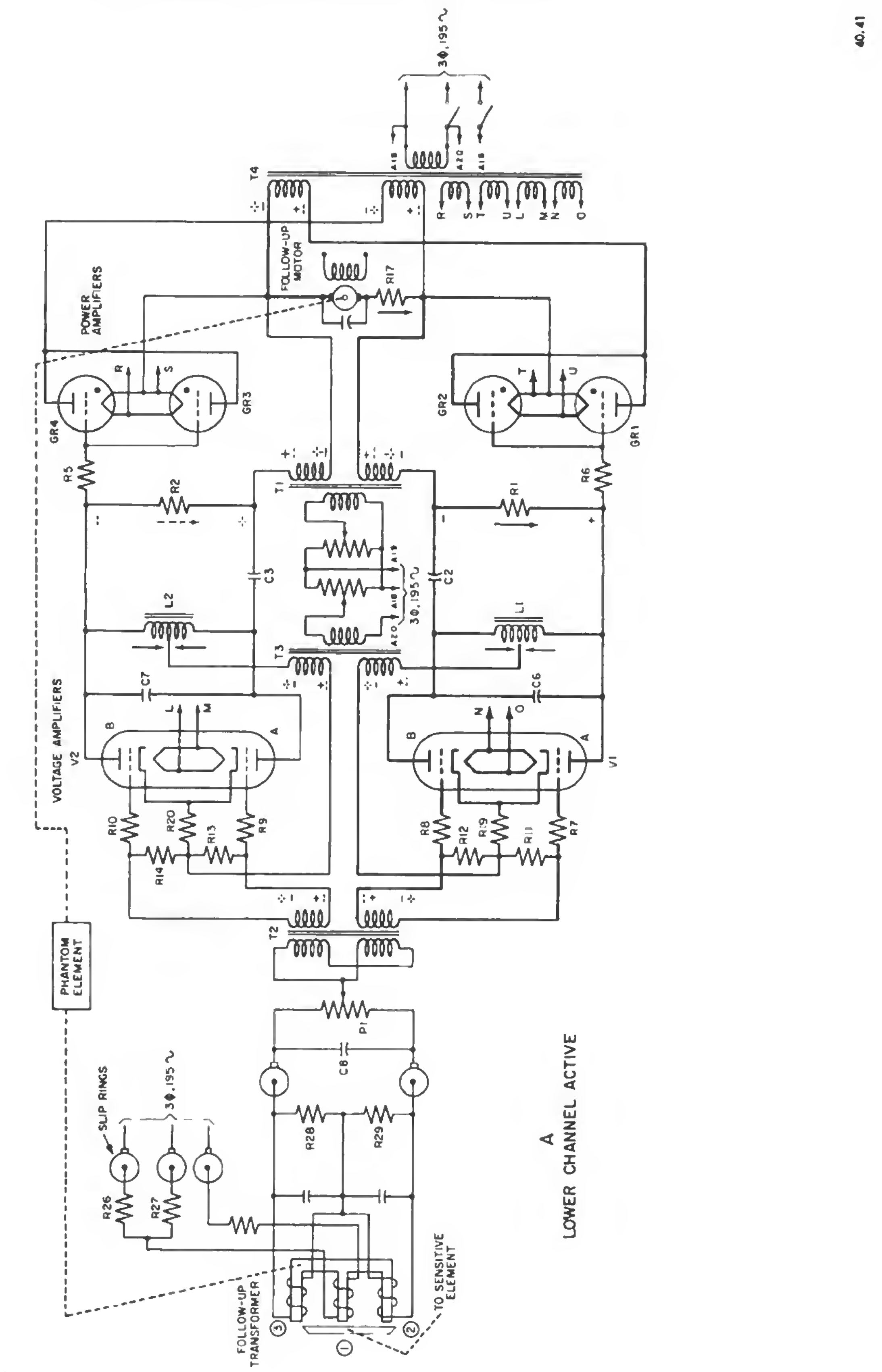
An armature carried on the sensitive element serves as a closing link in the double magnetic circuit of the followup transformer. The armature is positioned so that a small air gap is maintained between the armature and the transformer.

Secondary coils (2) and (3) on the outside legs of the transformer are connected in such a manner that the induced voltage in one leg is 180° out of phase with the induced voltage in the other leg. Small capacitors, connected across the secondary coils, are in parallel resonance with the coils at 195 cycles in order to obtain the maximum voltage across the coils at that frequency. To balance the voltage output of the secondary coils when the armature is centrally located, two fixed resistors are connected across the capacitors.

Operation of Followup Amplifier

When the sensitive element and the phantom element are in proper alignment, the voltages induced in coils (2) and (3) are equal, and the output voltage is zero. For this condition, the output signal from the voltage amplifier is zero, and the bias on the grids of the power amplifier tubes is such that a small plate current flows alternately in the GR1-GR2 group and the GR3-GR4 group. This current flows alternately in opposite directions through the followup motor armature, and therefore produces no motor torque. The purpose of this current is to keep the thyratrons warmed up and in readiness at all times to properly respond to a developed signal. A small displacement of the sensitive element from the phantom element in ONE direction unbalances the air gap in the magnetic circuit, thereby unbalancing the voltages induced in coils (2) and (3). The output voltage is the difference between these two voltages and the phase of the output voltage corresponds to that of the larger of the two voltages. Thus, if the sensitive element is displaced from the phantom element in the OPPOSITE direction, the unbalance of the coil voltages is inverted and the output signal is shifted 180°.

Unlike conventional electron-tube amplifiers, the plates of V1 and V2 are supplied with an a-c voltage instead of the usual d-c supply. The amplifier circuits (fig. 5-24) are arranged in two channels, (one in heavy lines, the other in light lines) one for each direction of rotation of the azimuth motor. The input circuits of each channel of the voltage amplifier are connected in pushpull, and the outputs are also connected in pushpull. The input signal is amplified in the voltage amplifier and applied to the thyratron grids to provide the proper gating action of the thyratrons. The plate circuits of the thyratrons are connected in series with the azimuth-motor armature and the secondary of the a-c power supply. This arrangement provides power to the azimuth-motor armature through either of two pairs of grid-controlled, parallel-connected, half-wave rectifiers—one pair for each direction of rotation. Only one channel at a time is active. For example, the plate voltages of V1A, V1B, and GR1-GR2 are all of the same



A
LOWER CHANNEL ACTIVE

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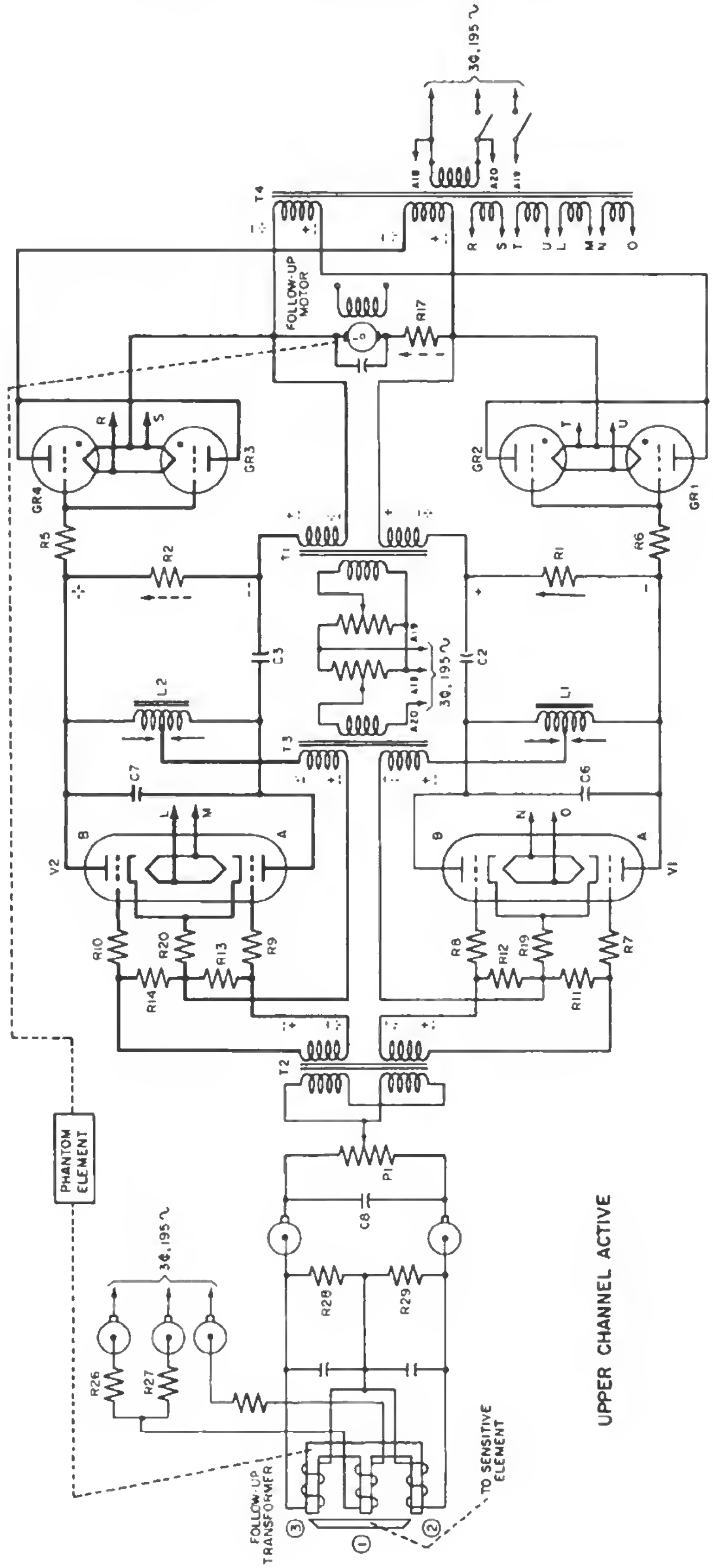

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Figure 5-24.—Sperry MK 11 Mod 6 gyrocompass followup system.

instantaneous polarity, and these tubes provide one of the two channels. Also the plate voltages of V2A, V2B, and GR3-GR4 have the same instantaneous polarity so that these tubes provide the second channel. The polarity of the plate voltages of the first channel is opposite to that of the second channel. In others words, they are 180° out of phase at all times.

For example, assume that the armature of the followup transformer is positioned so that the voltage induced in coil ② is larger than the voltage induced in coil ③. The input signal applied to T2 from the followup transformer is then assumed to be of a polarity that will cause the grid of V1A to go more negative (fig. 5-24A), and the grid of V1B to go more positive during the half cycle that the plates of V1 are positive. The secondaries of T2 are wound so that the grids of V1A and V2B have the same polarity at any instant. This signal will cause the plate current of V1A to decrease, and the plate current of V1B to increase. Thus a positive going signal will be applied to the grids of GR1-GR2, causing them to conduct. The polarities for the first half cycle are indicated by the solid polarity markings. Current will flow through the armature of the azimuth motor during this half cycle in the direction indicated by the solid arrow. The active channel is indicated in heavy lines. Twin triodes V2A and V2B do not conduct during this half cycle because their plates are negative.

During the second half cycle, the polarities reverse as indicated by the dotted polarity markings in figure 5-24A. Twin triode V1 does not conduct during this half cycle because the plates of V1A and V1B are negative. Rectifiers GR1-GR2 do not conduct because their plates are negative. The signal at transformer T2 makes the grid of V2A more negative and the grid of V2B more positive. Plate current increases in V2B and decreases in V2A. The negative-going output signal across R2 makes the grids of GR3-GR4 more negative, and these rectifiers are cutoff so that no current flows through the armature of the azimuth motor during this half cycle. Hence, half-wave pulses of plate current from GR1-GR2 flow through the azimuth motor, which moves the phantom ring into alinement with the sensitive element. This action reduces the input voltage to transformer T2 to zero.

In the absence of a signal voltage, the a-c bias equalizes the currents in the GR1-GR2 and the GR3-GR4 power amplifier tubes. The output current of GR1-GR2 reduces to a small keep-alive value which flows through the followup motor armature during a portion of alternate half cycles. The output current of GR3-GR4 flows through the followup motor armature in the opposite direction during an equal portion of succeeding half cycles, and the azimuth motor stops.

If the phantom and sensitive elements are displaced in the opposite direction so that the voltage induced in coil ③ is larger than that induced in coil ② (fig. 5-24B), the input signal to T2 will reverse its phase with respect to the a-c voltage supplied to the plates of V1 and V2. The polarities for the first half cycle are indicated by the solid polarity markings in figure 5-24B.

During the first half cycle the plates of V2A and V2B are negative and do not conduct, and the plates of rectifiers GR3-GR4 are also negative and these tubes do not conduct. A positive-going signal is applied to the grid of V1A and a negative-going signal to the grid of V1B. The plate current in V1A increases and in V1B decreases. The resulting signal across R1 is applied to the grids of GR1-GR2 as a negative-going signal, and these rectifiers do not conduct.

During the second half cycle the plates of V1A and V1B are negative (dotted polarity markings), and these tubes do not conduct. The plates of rectifiers GR1-GR2 are also negative, and these tubes do not conduct. The signal on T2 makes the grid of V2A positive and the grid of V2B negative during the time both plates of V2 are positive. Thus, plate current increases in V2A and decreases in V2B. The positive-going signal across R2 makes the grids of GR3-GR4 positive during the half cycle that the plates are positive, and these rectifiers conduct heavily. The active channel is indicated in heavy lines. Current flows through the armature of the azimuth motor in the direction indicated by the dotted arrow. Thus, half-wave pulses of plate current flow through the azimuth-motor armature in the direction indicated in figure 5-24B. This direction is opposite to that in figure 5-24A. The motor moves the phantom ring into alinement with the sensitive element and the input voltage to T2 is reduced to zero. This action reduces the signal across R2 to zero, and the azimuth motor stops.

Each channel has its own rate circuit which provides an antihunt voltage for the power tubes that it controls. The rate capacitors are C6 and C7.

During the time that the plates of the voltage amplifier triodes are negative on alternate half

cycles, the rate capacitors maintain the signal voltage across the choke coils in the output circuits of the voltage amplifiers. For example, in figure 5-24B, the signal developed in the active channel (heavy lines) charges rate capacitor C7 to the peak value of the signal voltage appearing across L2 and holds this voltage during the nonconducting half cycle as it slowly discharges through L2. As long as the signal holds up across L2, coupling capacitor C3 cannot discharge. As the signal diminishes because of the follow-up motor approaching synchronism, the magnitude of the signal voltage across L2 diminishes, thereby allowing C3 to discharge. This discharge sets up a negative-bias component across R2 that cuts off GR3-GR4 just before synchronism. This action permits the keep-alive current in GR1-GR2 to develop a motor torque in the opposite direction. Also before synchronism, the power amplifier tube that was firing for the greater length of the conducting half cycle with cutoff, allowing the other power amplifier tube to become more effective in reversing the motor torque so that over travel and hunting are prevented.

Tube Failure

There is an important feature about this followup circuit. It will continue to operate even if one of the voltage amplifier tubes and one of each pair of power amplifier tubes should fail. The remaining voltage amplifier and one of each pair of power tubes, a total of three tubes, will keep the system operating.

In normal operation each pair of power tubes passes a current of about 0.4 ampere when there is no signal on the grids. These currents are in opposite directions, and cancel each other as far as their effect on the azimuth motor is concerned. When the phantom moves to one side or the other, the current passed by one pair of tubes is increased, and that passed by the other pair is decreased. The difference between the currents passed by the two pairs of tubes is the resultant current that operates the azimuth motor.

If one channel of the voltage amplifier is not operating, its pair of power tubes will pass a current of 0.4 ampere regardless of the position of the phantom. The other pair, being controlled by the active section of the voltage amplifier, passes more or less than 0.4 ampere, depending upon the position of the phantom. Thus, a difference in current still exists between the two pairs of power output tubes that is sufficient to operate the azimuth motor. Since only one of each pair of power tubes ordinarily operates, the failure of one tube in each pair has no effect on the functioning of the circuit.

TRANSMISSION SYSTEM

The Sperry Mk XI Mod 6 gyrocompass transmission system provides a means of transmitting the readings of the master gyrocompass to a number of repeater compasses located at various stations in the ship. The 1-speed and 36-speed synchro transmitters (driven by the azimuth followup motor) control the movement of the repeater compasses that indicate the readings of the master compass at the remote stations.

The transmission system also includes the transmitter overload relays, repeater panel, relay transmitter repeater panel, relay transmitter, relay transmitter amplifier panel, differential alarm relay, and repeater compasses.

Transmitter Overload Relays

Two similar transmitter overload relays, mounted on the back of the compass control panel, provide a visual alarm when an overload occurs in the transmitter circuits. One relay is connected in the 1-speed transmitter circuit, and the other relay is connected in the 36-speed transmitter circuit (fig. 5-25). The relay consists of three legs with a coil on each leg. Each coil is connected in series with a transmitter stator lead. An increase in the current through any or all of the coils above a critical value attracts the relay armature, causing it to move. This action closes a contact that lights a red signal lamp on the panel front, indicating trouble in the transmitter circuit. A 115/7-volt transformer on the panel supplies the indicator lamp circuits.

Repeater Panel

The repeater panel (fig. 5-2) is located below the followup panel. It comprises an assembly of rotary switches, and auxiliary equipment. Each switch with its associated fuses and overload indicating devices is assembled as a unit and can be withdrawn from the front of the panel for inspection and repair.

Each compass repeater switch is arranged to connect the circuits of two repeater compasses

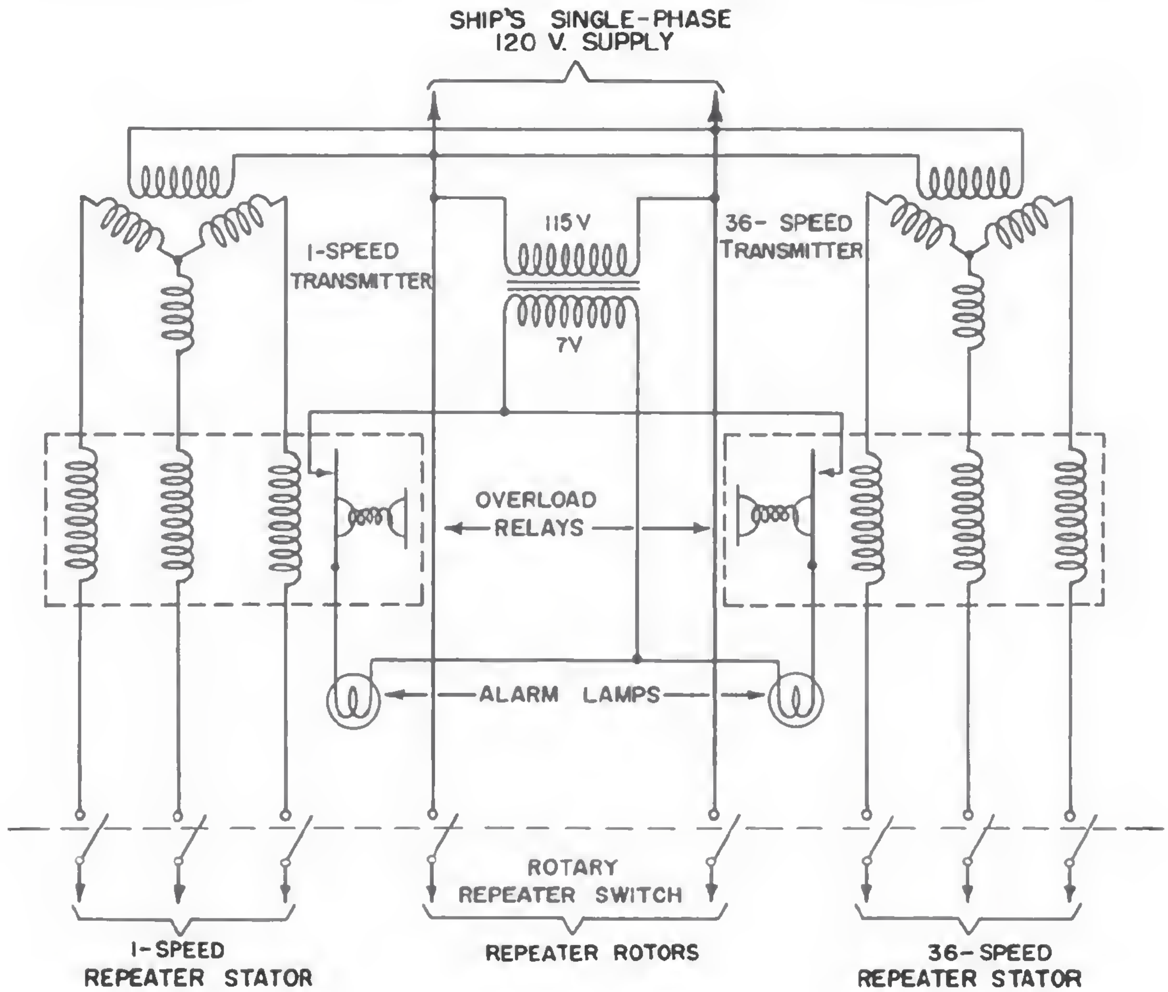


Figure 5-25.—Sperry Mk 11 Mod 6 gyrocompass transmitter overload relay circuit.

so that either one, or both, may be driven by the master compass transmitters.

Each repeater circuit, whether 1-speed or 36-speed, is provided with an overload indicator, comprising a transformer and a neon lamp. The transformer has two primaries, which are connected in series respectively with two of the three secondary leads to the repeater. The transformer secondary is connected across the neon lamp. When the repeater is approximately alined with the transmitter, the very small current in the transformer primaries does not generate sufficient voltage across the secondary to illuminate the lamp. However, excessive current in the transformer primaries causes the lamp to glow and thus indicate trouble in this repeater circuit.

Associated with each of the repeater circuit switches are four fuses, access to which is through the hinged door just above the switch handle. Two of the fuses are in the primary circuit to the 1-speed repeater, and the remaining two are in the primary circuit to the 36-speed repeater.

The rotary-type switch designated on the panel as the fire control switch is not provided with an overload alarm because connections are made from this switch to the fire control switchboard, which has an alarm for each circuit leaving the board. However, at the fire control switch on the repeater panel the two indicators are (1) a pilot lamp, connected across the a-c supply to this switch and therefore illuminated as long as this supply is available, and (2) a

transformer and neon lamp arranged to indicate when one or both of the a-c supply fuses blows.

The fuses are on the load side of the switch. The transformer has two primaries, one of which is connected across the 120-volt leads on the supply side of the fuses, while the other is connected across the same leads on the load side of the fuses. The two primaries are arranged so that normally their magnetomotive forces are in opposition, giving zero voltage across the secondary. However, failure of one or both fuses cuts out the primary on the load side of the fuses so that the remaining primary induces the secondary voltage, and thereby lights the neon lamps.

The rotary-type switch designated on the panel as the dead reckoning analyzer switch is provided to operate the DRA from the underwater log transmitter and the 1-speed transmitter on the master compass. This switch also supplies single-phase, 120-volt, a-c power and 120-volt, d-c power necessary for the operation of the DRA. Each of these circuits is provided with two fuses. A neon lamp across each fuse in the d-c circuit is lighted when a fuse blows in the circuit. A transformer and neon-lamp overload indicator (similar to the indicators in the repeater circuits) is connected in the 1-speed compass transmitter secondary to the own ship's course motor in the DRA.

Relay Transmitter Repeater Panel

The relay transmitter repeater panel (fig. 5-22) is located adjacent to the repeater panel. This panel and the previously described repeater panel are arranged so that the repeater compasses can be connected to either the master-compass transmitter or to the relay transmitter, as shown in figure 5-26. The relay transmitter (described later) is an intermediate self-synchronous transmitter provided in the transmission system to actuate a number of compass repeaters without placing this load directly on the master compass transmitters.

The relay transmitter repeater panel includes eight rotary switches. These include a checking repeater switch, a fire control switch, a relay transmitter supply switch, an emergency navigation transfer switch, two compass repeater switches, and two radar mast (special) switches.

The checking repeater switch connects the gyrocompass-room checking repeater either to the master compass or to the relay transmitter. Two fuses are connected in series with the primary leads on the load side of the switch. Two transformer and neon-lamp overload indicators (one of each circuit) are connected in the transmitter secondary circuits to indicate an overload in these circuits. These indicators are similar to the overload indicators previously described in the repeater circuits.

The fire control switch is connected only to the master-compass transmitter. The same blown-fuse indication is provided with this switch as that described for the fire-control switch on the repeater panel.

The relay transmitter supply switch connects the master-compass transmitters to the relay transmitter. A (green) pilot lamp indicates when the circuit to the relay transmitter is closed. A transformer and neon-lamp overload indicator provides a blown-fuse indication.

The emergency navigation transfer switch connects certain of the ships repeater compasses either to the master compass or to the relay transmitter. A red and green pilot lamp and four fuses are provided on the panel. The red pilot lamp indicates that the master signal cable to the compass control panel is energized. The green pilot lamp indicates that the repeater supply is available to the relay transmitter repeater panel. Two fuses are connected in each of the pilot lamp circuits.

Each compass repeater switch is arranged to connect two repeater compass circuits so that either one or both can be controlled by the master compass by way of the relay transmitter. The same blown-fuse indication is provided with each switch as is provided for each compass repeater switch on the repeater panel.

Each radar mast switch (special) is arranged to connect two mast radar cables to the transmission system so that either one or both can receive the ship's course indication from the master compass via the relay transmitter. A fuse is provided in each of the primary leads of a mast radar cable. A transformer and neon lamp are provided in the circuit that is similar to the one previously described to indicate a blown-fuse condition. A green pilot lamp, across the primary on the load side of the fuse, indicates when the circuit is energized.

Relay Transmitter

In order to actuate a number of repeater compasses without imposing this load directly on the compass transmitters, an intermediate

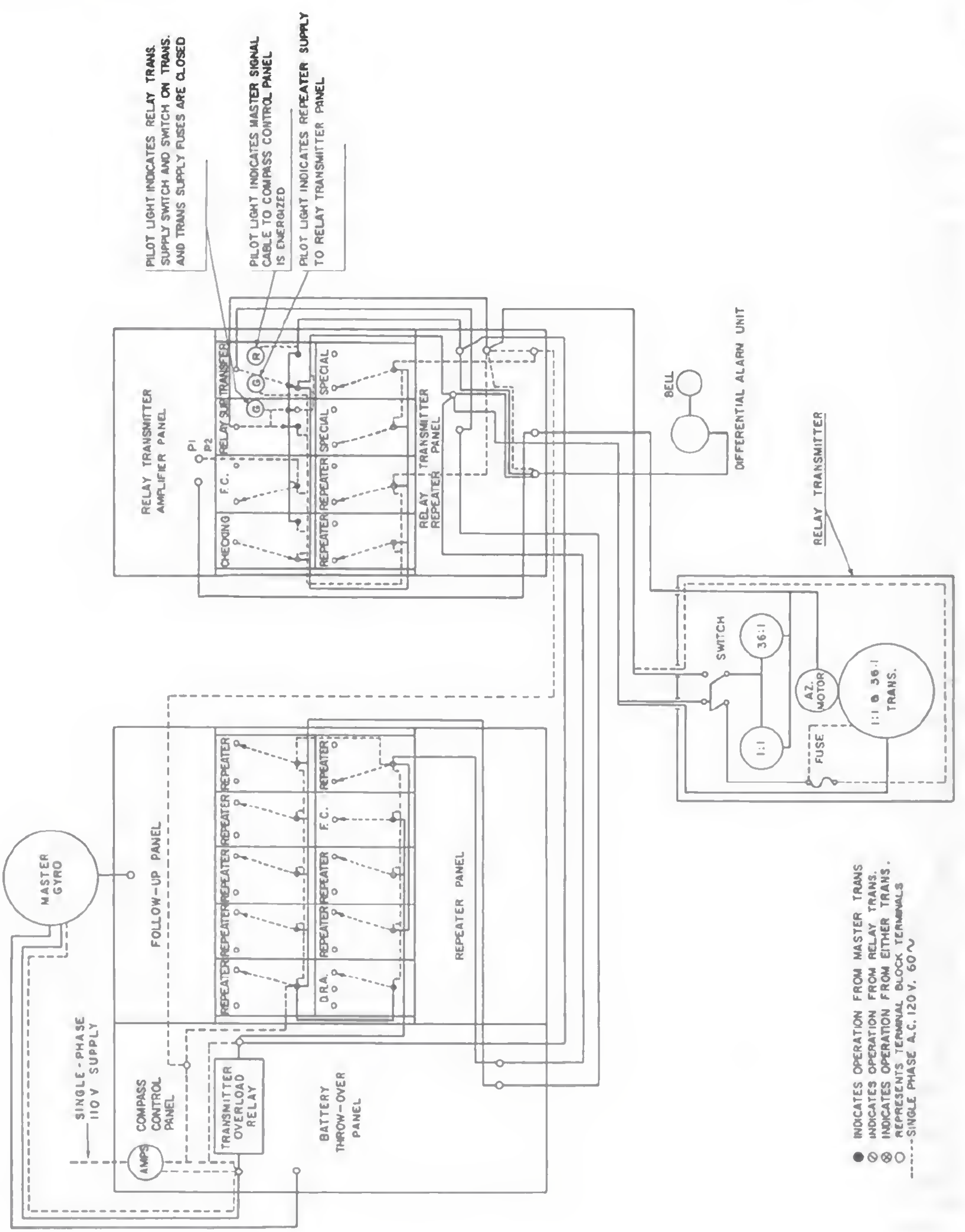


Figure 5-26.—Sperry MK 11 Mod 6 gyrocompass relaytransmitter.

instrument known as a relay transmitter is used. The relay transmitter (fig. 5-27) consists of a 1-speed and a 36-speed synchro control transformer (CT) , a commutator transmitter, a followup motor, and a reactor. These components are enclosed with a metal case provided for bulkhead mounting (fig. 5-27A).

The relay transmitter is synchronized with the master compass by means of the synchro control transformer (fig. 5-27B), followup motor, and relay-transmitter amplifier. The controlling signai voltage from the master compass energizes the primaries of the control transformers. The output of the control transformers is fed to the amplifier, the output of which controls the followup motor. The followup motor drives a commutator-type transmitter, the output of which energizes the repeaters, causing them to follow the master compass. The followup motor also drives the secondaries of the control transformers to the zero-voltage position, thereby synchronizing the relay transmitter with the master compass.

The commutator transmitter is essentially a stationary Gramme ring winding with taps, each of which is connected to a commutator segment. The 1-speed (outer) and the 36-speed (inner) set of commutator brushes are rotatable. They are concentrically mounted and bear on a flat stationary commutator. Each set comprises three brushes marked "blue," "green," and "red," respectively. Three commutator bars are similarly marked.

When the transmitter is on electrical zero, the blue brushes are in the center of the blue commutator bar. The "red" and "green" brushes on the 1-speed set are located 120° 20' from the "blue" brush; whereas, the "red" and "green" brushes on the 36-speed set are located 119° 40' from the "blue" brush.

The 1-speed and 36-speed commutator brushes are connected respectively to the concentrically mounted 1-speed and 36-speed slip rings. Each set comprises three slip rings with brushes that are connected to leads from the repeater panel.

In the operation of the commutator transmitter, the three voltages selected by each set of brushes correspond to the secondary output of a conventional-type snychro transmitter. However, the increase or decrease in the output voltage is not as smooth as in the conventional-type synchro, but occurs in steps that depend on the number of commutator bars and brushes used in the commutator transmitter. There are 360 commutator bars corresponding to 360° of rotation for the 1-speed circuit. Since there are three brush positions approximately 120° apart, three voltage steps will occur for each degree of rotation. A reactor, connected in shunt with the single-phase, 120-volt 60-cycle input stabilizes the current supplied with varying load, thereby improving the performance of the commutator transmitter.

The six stator leads from the 1-speed and 36-speed master-compass transmitters (fig. 5-27B) are fed to a terminal block in the relay transmitter and then through six poles of an 8-pole switch to the respective primaries (stators) of the 1-speed and 36-speed synchro control transformers. The voltages induced in the secondaries (rotors) of the control transformers are fed to the relay transmitter amplifier. The output of this amplifier drives the followup motor that causes the commutator transmitter to follow the master compass.

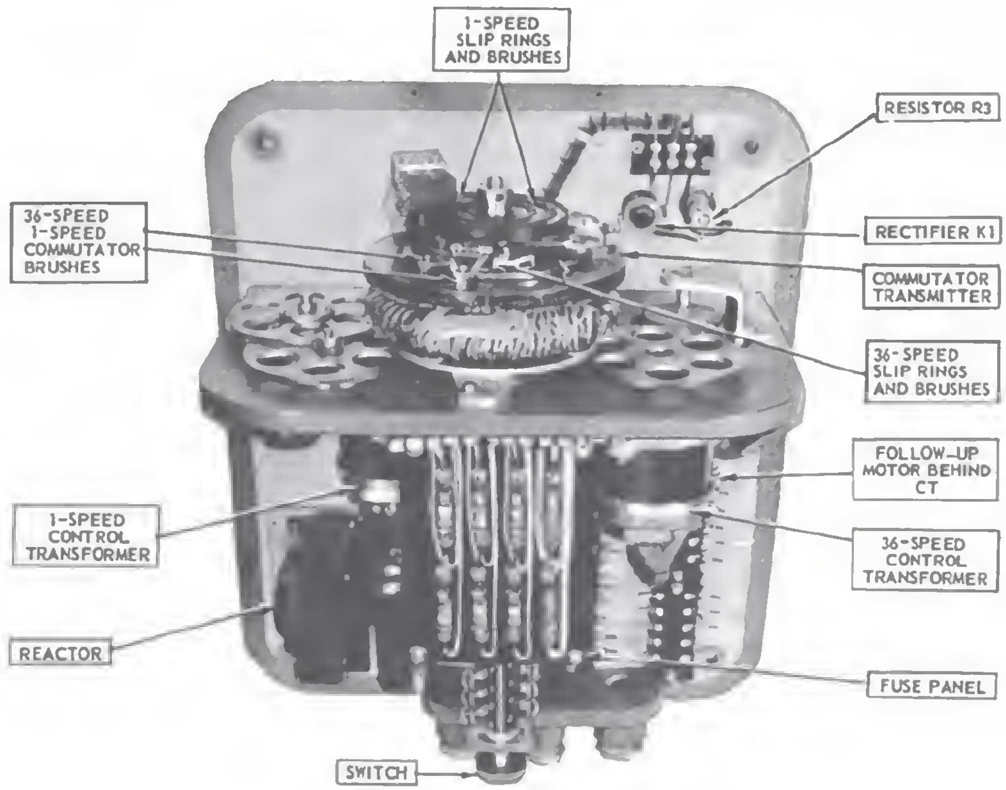
The single-phase, 120-volt, 60-cycle supply does not pass through the 8-pole switch, but is fed directly from the terminal block through two fuses to the reactor and commutator transmitter. However, the 120-volt supply to the pilot lamp is fed through two poles of this switch.

Relay Transmitter Amplifier Panel

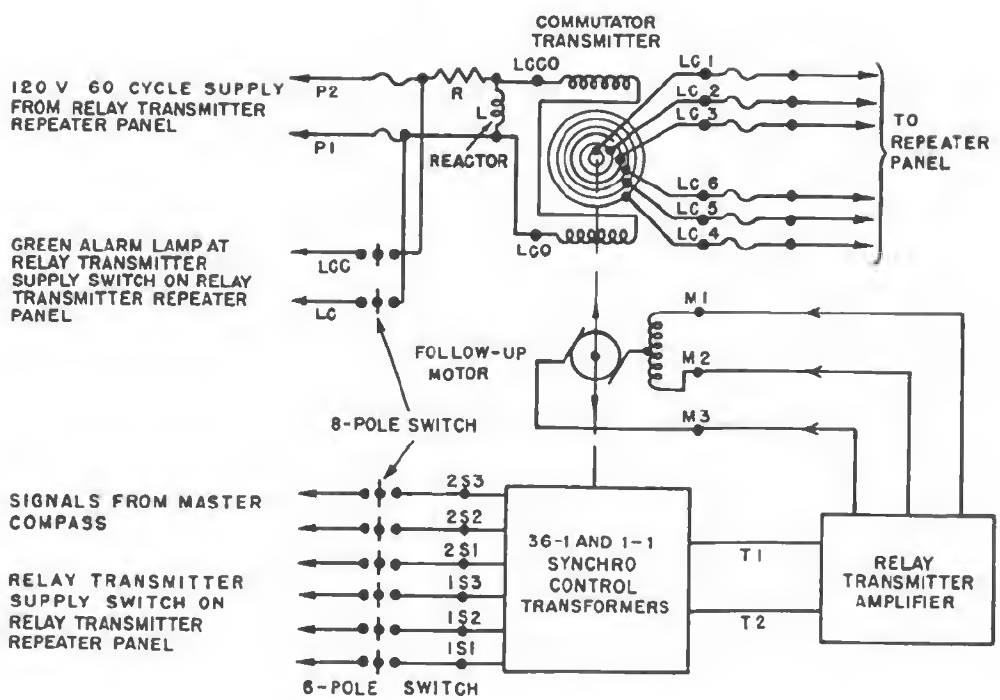
The relay transmitter amplifier panel (fig. 5-22) is located adjacent to the followup panel. If consists of a voltage amplifier and a power amplifier. A schematic of the relay transmitter amplifier circuits is indicated in figure 5-28. The voltage amplifier, V1, receives the signal from the control transformers, and the output is fed to the power amplifier, GR1-GR2. The power amplifier provides the controlled power necessary to operate the followup motor in response to the signals from the voltage amplifier.

The voltage amplifier consists of twin triod V1A and V1B. The voltage induced in the secondaries (rotors) of the 1-speed and the 36-speed control transformers by a displacement between the master-compass transmitter and the commutator transmitter is fed to the voltage amplifier through the primary of the input transformer, T1. The magnitude of the signal voltage is controlled by potentiometer P3. The secondary of T1 supplies the grids of V1 through the phase shifting network, C4, C5, R9 and R10.

The power amplifier consists of thyratrons GR1 and GR2. The output of V1 is fed to the grids of GR1 and GR2 through C9 and C10. The output of GR1 and GR2 energizes the followup



A. INTERNAL VIEW



B. SCHEMATIC DIAGRAM

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Figure 5-27.—Sperry Mk 11 Mod 6 gyrocompass relay transmitter.

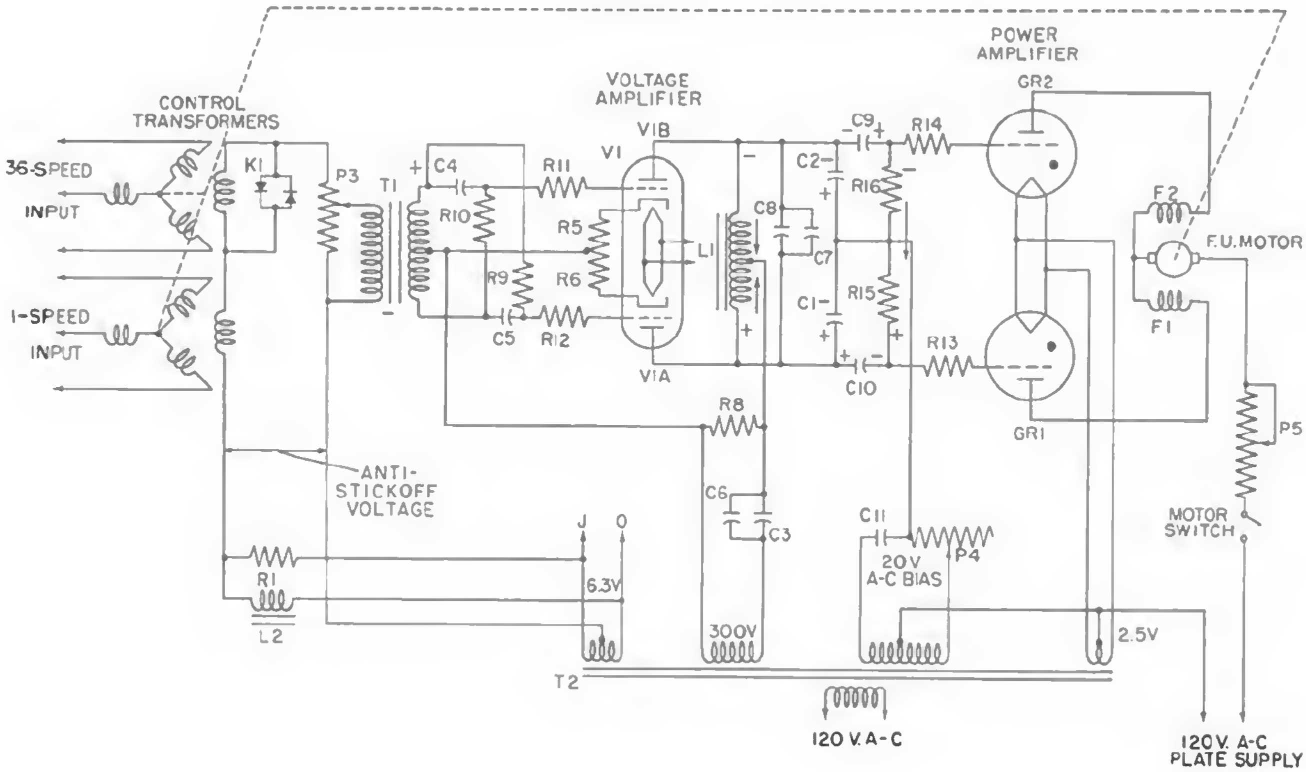

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Figure 5-28.—Sperry Mk 11 Mod 6 gyrocompass relay transmitter amplifier.

motor. The plate voltages of the thyratrons are derived from the same 60-cycle, 120-volt source that supplies the plates of the voltage amplifiers and the synchro control transformers.

With no signal applied to T1, the cathode bias on the grids of V1A and V1B limits the plate current to equal values in both sections of the twin triode. Thus, the currents in both halves of choke L1 are equal magnitude. Because these currents flow in opposite directions (outside to center tap of choke), the net voltage drop across L1 is limited to a small d-c component, and no a-c signal component appears across L1. With no signal applied to the grids of GR1 and GR2, the a-c bias on the power amplifier tubes is such that the thyratron plate currents flow for a small part of the conducting half cycle. With equal currents in the two opposing fields of the followup motor, no torque is developed and the motor does not operate. Plate supply for all tubes in the amplifier is from the same a-c source so that plate currents flow in pulses during the half cycle that the plates are positive.

When a signal is applied to T1, an output signal is developed, and the followup motor operates to reduce the signal to zero, at which time the motor stops.

On the first half cycle of the applied signal, one grid of twin triode V1 is driven in a positive direction as the other grid is driven in a negative direction with respect to the common cathode. On the next half cycle, the polarities of the grids reverse, but this reversal can be disregarded because the plates of the amplifier tubes are negative at this time and no conduction occurs.

If an input signal is applied to T1 and is of a polarity such that the grid of V1A swings more negative and the grid of V1B swings more positive, the plate current of V1A will decrease, and that of V1B will increase. This action causes a potential difference to be set up across choke L1, the polarity of which is minus at the top and plus at the bottom. It is across L1 that the signal for the thyratrons is developed. The polarity of this signal depends on the half of V1 that is conducting more heavily.

In this case, section V1B will pass an increasing current through the upper half of L1, and section V1A will pass a decreasing current through the lower half of L1. The induced voltage across L1 makes the grid of GR2 more negative and the grid of GR1 more positive. This voltage also charges the rate capacitors C1, C2, C7, and C8. The polarities are indicated in the figure.

Thus, GR1 passes a higher average current than GR2 because it conducts for a longer period during the conducting half cycle. Thus, the followup motor field, F1, will be stronger than field, F2, and the followup motor will drive the relay transmitter into alignment with the master compass.

The rate capacitors, C1, C2, C7, and C8, maintain the potential across the choke, L1, on alternate half cycles when the plates of the tubes are negative by discharging through L1. As long as the potential exists across L1, the coupling capacitors, C9 and C10, cannot discharge. When the signal gradually decreases because of the relay transmitter approaching synchronism, the signal voltage across L1 also decreases, allowing C9 and C10 to discharge through R15 and R16 in the opposite direction to that of the signal voltage indicated by the arrow. This discharge provides a more negative bias for the controlling tube, GR1, and a more positive bias for the opposing tube, GR2. Hence, before the relay transmitter reaches synchronism, the controlling tube, GR1, is cut off, and the torque of the followup motor is reversed to prevent overtravel and hunting.

Normally, the controlling signal voltage for the relay transmitter is obtained from the 36-speed control transformer. The relay transmitter is made self-synchronous by properly combining the outputs of the 1-speed and the 36-speed control transformers. If the relay transmitter is more than 5° from the synchronous position, the voltage limiter, K1, limits the peak output voltage of the 36-speed control transformer so that the voltage of the 1-speed control transformer is greater and controls the amplifier. Conversely, if the relay transmitter is less than 5° from the synchronous position, the output voltage of the 36-speed control transformer is greater and controls the amplifier.

The voltage limiter, K1, consists of two copper oxide rectifiers connected in opposition and shunted across the secondary (rotor) of the 36-speed control transformer. The rectifiers offer nonlinear resistance with increasing voltage, that is, they offer almost no resistance to high voltages and a very high resistance to low voltages.

Antistickoff Voltage

A difficulty that must be overcome in a 2-speed system is the possibility that the system will lock in at 180° error angle. At this angle both the 1-speed and the 36-speed control transformer rotor voltages will be zero; the 36-speed rotor is a true zero because it goes through a true zero every 10°. If the error angle is within 2.5° of the 180° position, the 36-speed control transformer is in control, causing the system to lag 180°. To prevent this condition from developing, the following circuits are used:

The 1-speed control transformer rotor is shifted so that a voltage equal to a 6° displacement (about 3 volts) is induced in the rotor winding when the system is at 0° or in correspondence with the master compass.

The network consisting of L2 and R1 is supplied by the 6.3 volt secondary of power transformer T2. This voltage (an antistickoff voltage of 3 volts) combines with the output voltage of the 1-speed control transformer to produce zero voltage at 0°. At the 180° position, the induced voltage of the 1-speed control transformed rotor reverses its phase with respect to the antistickoff voltage so that the total voltage is 3 + 3 or 6 volts, and this signal continues to drive the system beyond 180° to the true point of correspondence. The advantage of this system is that it now has only one zero position instead of two.

Differential Alarm Relay

The differential alarm relay (fig. 5-29) is a device for sounding an alarm whenever the relay transmitter loses synchronism with the master compass. The amount by which the transmitter is allowed to diverge, before the alarm is sounded, is adjustable from 0° to 2.5 .

The device comprises a synchro differential receiver. The stator receives its signal from the 36-speed output of the relay transmitter: the rotor circuit receives its signal from the 36-speed transmitter at the master compass. As long as the two outputs are in agreement. the rotor remains at the neutral position. Failure of the relay transmitter to keep in synchronism causes the rotor to move from the

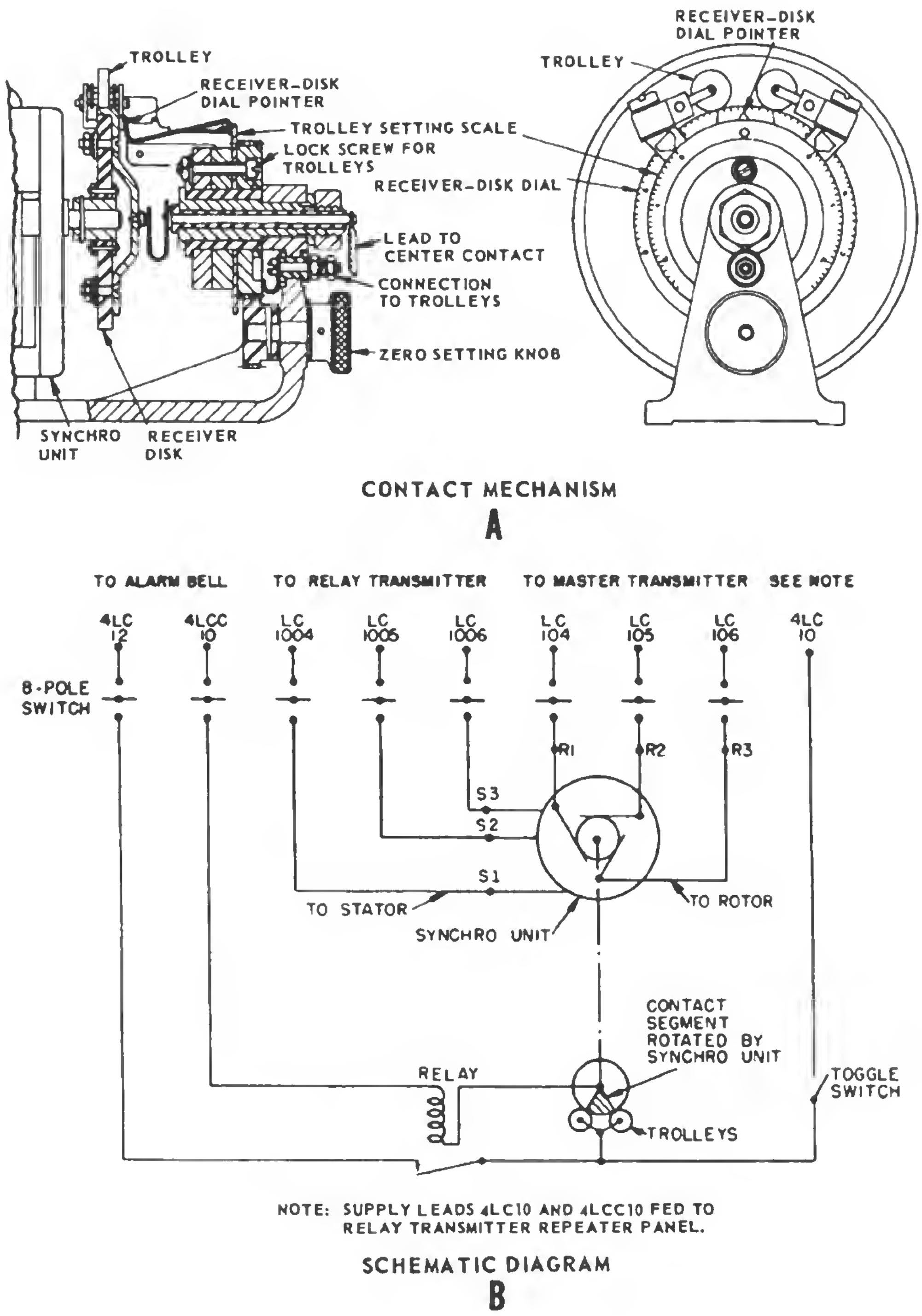

Figure 5-29.—Sperry MK 11 Mod 6 gyrocompass differential alarm relay.

neutral position to that amount corresponding to the divergence from synchronism.

A bakelite disk that has a metallic segment is mounted on the shaft of the differential receiver (fig. 5-29, A). Two trolleys bear on the periphery of the disk. These trolleys are arranged so that rotation of the disk causes one trolley to contact the metallic segment. This action closes the 120-volt, a-c circuit to a relay (fig. 5-29, B), which in turn closes the 120-volt, a-c supply to the alarm bells located in the pilot house.

A dial on the differential-receiver disk (mounted on the shaft) indicates the position of the rotor (fig. 5-29, A). This dial is graduated in 0.1° steps from 0° to 3° in each direction from the 0° position. The dial pointer is mounted on the trolley assembly and is normally opposite the zero mark on the dial. A zero-setting knob is provided for setting the trolley assembly on the zero position with respect to the dial.

The two trolleys can be set independently to allow for a divergence up to 2.5° before the alarm is sounded. Each trolley support has a pointer that is read against a trolley setting scale (fig. 5-29, A). When the pointer is opposite the zero mark on this scale, the trolley makes contact with the edge of the metallic segment (assuming the receiver disk is in the neutral position). This position corresponds to the position of no permissible divergence. Normally, the trolley is set back on its scale to allow a predetermined divergence.

An 8-pole switch on the relay transmitter repeater panel is provided for disconnecting the differential synchro receiver and the alarm circuit (fig. 5-29, B). The toggle switch disconnects only the alarm circuit.

AUTOMATIC CORRECTION DEVICES

The Sperry Mk XI Mod 6 gyrocompass is provided with two automatic devices associated with error correction. They are (1) an automatic speed corrector associated with speed course, latitude error correction and (2) an automatic damping eliminator which prevents the introduction of ballistic damping errors during rapid changes in ship's speed or course.

Automatic Speed Corrector

The SPERRY AUTOMATIC SPEED CORRECTOR (fig. 5-30) automatically transmits corrections for the ship's speed to the speed correction mechanism on the master compass. The step-by-step motor geared to the corrector spindle on the speed correction mechanism (fig. 5-31) is remotely controlled by a step-by-step transmitter in the automatic speed corrector. A switch is mounted on the compass for opening the motor circuit when setting the correction device by hand.

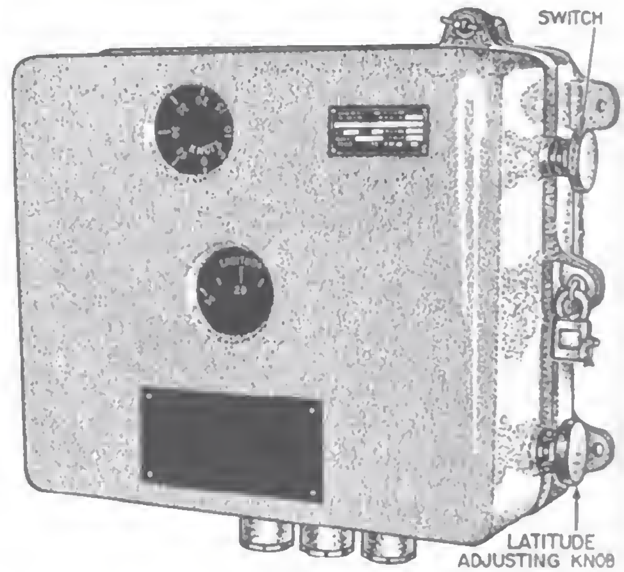

Figure 5-30.—Sperry automatic speed corrector.

The automatic speed corrector is contained in a metal box, mounted on the bulkhead in the vicinity of the master compass.

The ship's speed is introduced into the automatic speed corrector by a synchro motor (not shown) controlled by the underwater log (fig. 5-32). In operation, the rotor of the synchro motor takes a position representing the ship's speed and correspondingly locates a pair of trolleys bearing on a followup ring assembly.

When the position of the trolleys is not on the gap in the followup contact rings, the followup motor is energized. The motor drives a three-dimensioned cam, which, by means of a follower and gears, drives the followup contact rings into synchronism with the trolleys. The cam is designed so that when it is correctly positioned lengthwise for the local latitude, the amount it must turn to synchronize the trolleys and rings is proportional to the speed

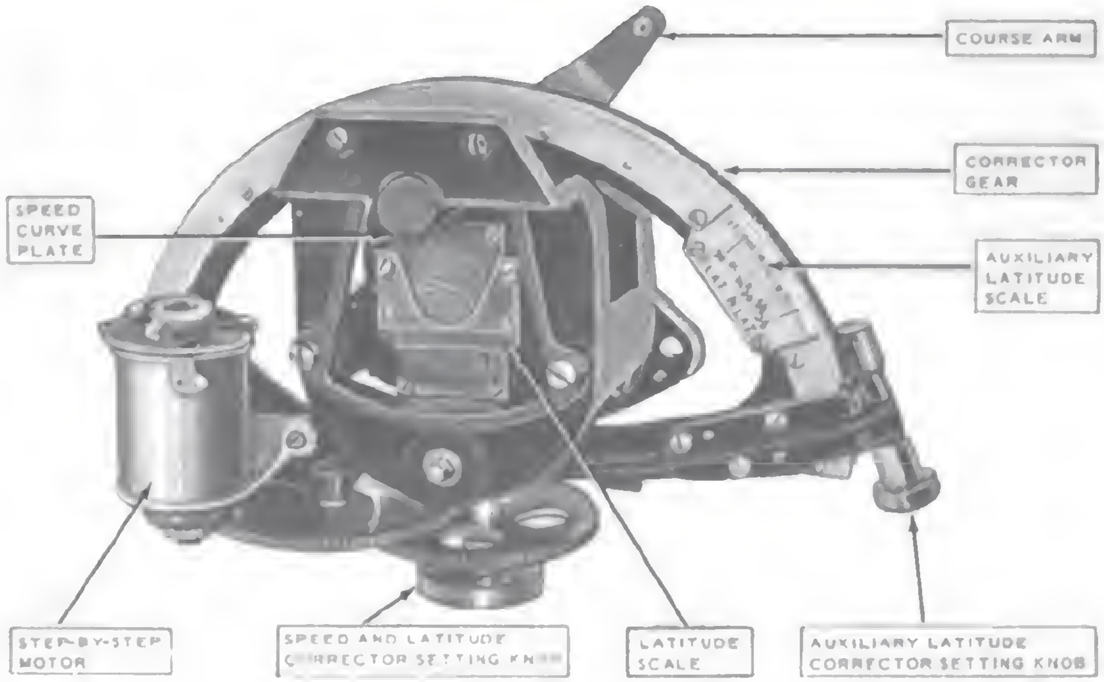

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Figure 5-31.—Speed correction mechanism.

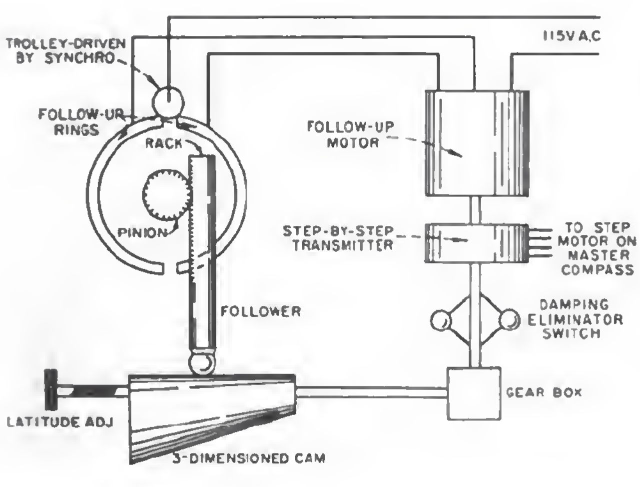

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Figure 5-32.—Schematic diagram of Sperry automatic speed corrector.

correction that must be set into the compass. This correction is transmitted to the compass by a step-by-step transmitter driven by the followup motor that rotates the cam. The motor also drives a centrifugal type damping eliminator switch to eliminate damping during rapid changes in speed.

The instrument is provided with a dial to indicate the ship's speed, graduated in knots and visible through a window in the cover. The latitude adjustment, which determines the lengthwise position of the three-dimensioned cam, is shown on another dial, also visible through a window in the cover.

When the ship is moving at a constant speed, the synchro remains stationary, and the trolleys rest on the insulated, or dead, segments of the followup rings. In this condition the circuit to the followup motor is open, and the automatic speed corrector is inoperative.

However, when the ship's speed changes, the synchromotor receives the indication of the changing speed from the synchro transmitter of

the underwater log, and the rotor takes a position to indicate this speed. This shifts the trolleys off the dead segments of the followup rings onto the contact segments. The followup motor then drives the step-by-step transmitter and the three-dimensioned cam. Rotation of the cam shifts the follower as required to match the followup rings with the position of the trolleys. When this has been done, the trolleys again rest on the dead segments, the motor stops, and with it the cam and the transmitter. During the cycle of operation, the transmitter has driven the corrector motor on the master compass so as to put in the required correction.

In higher latitudes, the corrector has to be adjusted to set in a greater amount of correction at the compass. To do this you set the latitude knob so that the dial indicates the correct latitude. Turning the knob to a higher latitude reaching moves the three-dimensioned cam lengthwise to a position where its shape is such that it has to be rotated through a larger angle to move the follower the same distance. Consequently, the followup motor has to drive a greater amount in order to shift the cam follower so that it will match the position of the trolleys. In this process the commutator transmitter is moved a greater amount and causes the step-by-step motor at the compass to set in a larger correction.

Automatic Damping Eliminator

The automatic damping eliminator used with the Sperry Mk XI Mode 6 compass (fig. 5-33) consists of two centrifugal switches, one geared to the azimuth motor, and one to the followup motor of the automatic speed corrector; and an electromagnet that moves the mercury ballistic connecting arm from its offset position to a true vertical position.

The switch geared to the azimuth motor takes care of changes in course where no change in speed is involved. This switch consists of a flyball governor driven through a gear train which speeds the governor shaft to about 4300 revolutions to one revolution of the phantom. To eliminate constant starting and stopping of the governor when the ship is yawing, a lost-motion mechanism and a helical driving spring are inserted between the switch driving gear in the azimuth motor train and the first gear in the train to the governor shaft. As the ship yaws, the lost-motion mechanism comes into

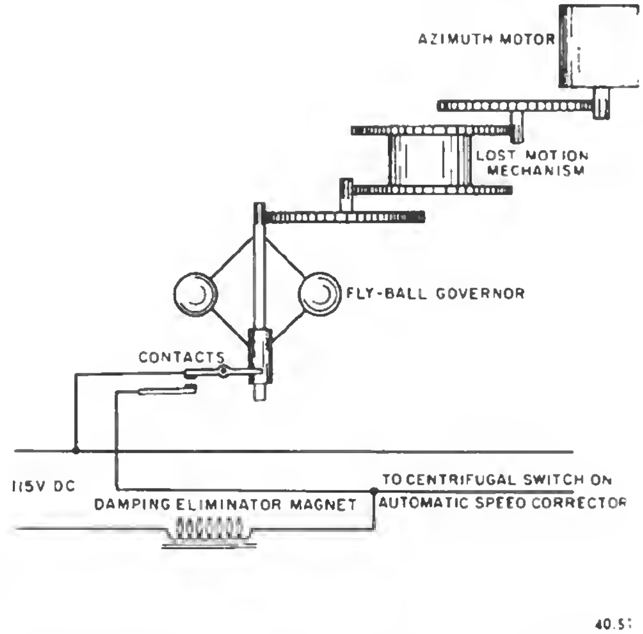


Figure 5-33.—Schematic diagram of Sperry automatic damping eliminator.

play. This mechanism prevents transmission of motion to the governor shaft.

If the ship turns more than 15 degrees, the helical spring is wound in one direction or the other until there is sufficient tension in the spring to set the governor in motion. As the governor spins, the balls fly up, raising a sliding collar on the governor shaft which engages an arm operating the magnet circuit contact, thus closing the 115-volt d-c supply circuit to the damping eliminator magnet.

A friction brake on the governor, and a spring disk friction clutch in the gear train, prevent the governor from spinning too fast. The contacts are adjusted so that the circuit is closed when the ship turns at a rate of more than 40 degrees per minute.

The gearing arrangement from the azimuth motor through the lost motion device to the flyball governor is shown in figure 5-23. Note also in this figure that any error correction applied to the master compass automatically shifts the synchro transmitter stators rather than their rotors as explained previously for older mark compasses.

The damping eliminator switch (fig. 5-32) driven by the followup motor in the automatic speed corrector operates in a similar manner to eliminate damping during rapid changes in ship's speed.

SELF-SYNCHRONOUS ALIDADE

The Sperry self-synchronous alidade, or alidade bearing repeater, is essentially a bearing repeater compass with a card driven by a followup motor, so that it is turned with sufficient torque to permit a telescope or other observing instrument to be mounted directly upon it for the purpose of taking accurate true bearings.

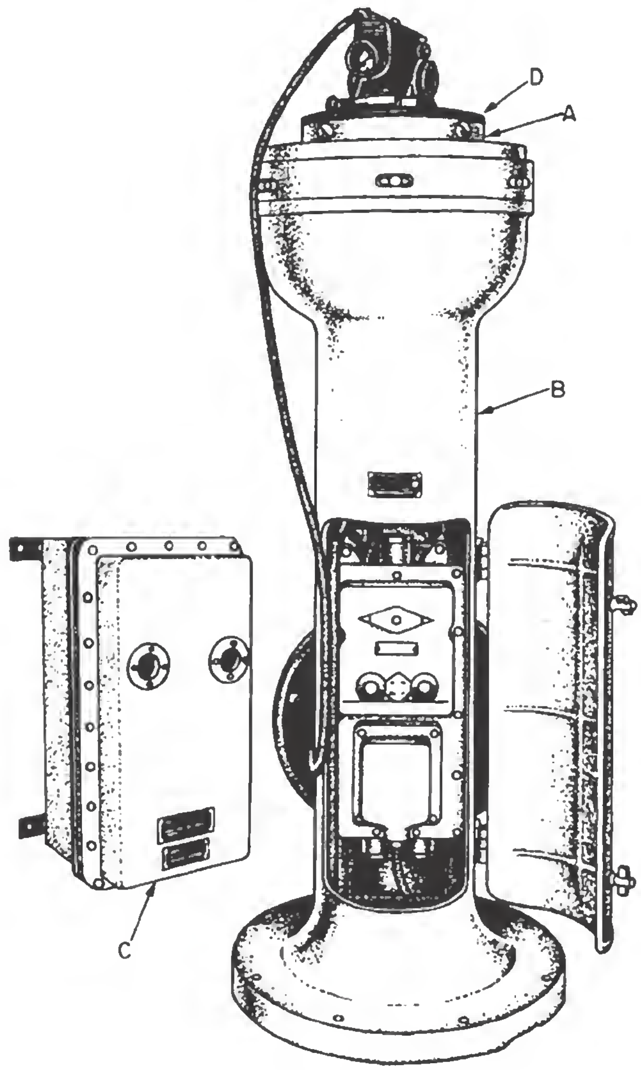
The card of a gyrocompass repeater is held in azimuth by the master compass, and the ship moves about. When taking astronomical or terrestial bearings from a moving ship (if the observing instrument is mounted on the pelorus stand, which moves with the ship) you must keep the instrument accurately aligned on the object and at the same time obtain an accurate azimuth reading from a compass card that moves continuously with respect to the instrument. These instantaneous readings cannot be very accurate, however, and, once taken, there is no means of checking them.

The self-synchronous alidade overcomes this difficulty by permitting the telescope to be mounted directly on the card, so that it also remains fixed in azimuth. Since the telescope is not moving about with respect to the object being observed, the taking of accurate bearings is greatly simplified. Because the telescope is mounted directly on the card, once an observation has been taken, the the true bearing—as indicated by the card reading opposite the telescope index—remains available for checking until the telescope is moved.

This alidade consists of stand and gimbals, repeater, telescope assembly, and amplifier. Refer to figure 5-34. The stand, B, is a hollow cylinder with base and bowl-shaped top. The bowl and gimbal mounting permit the repeater, A, to remain steady during a 60° roll or 30° pitch. The stand has a metal cover which does not interfere with the telescope assembly and its mount, D.

The amplifier, C, is housed nearby in a watertight box designed for bulkhead mounting although its controls, illumination dimmers, and switches are in the column of the stand, B.

The repeater assembly, A, includes the synchro control transformers, reversible followup motor, gearing (essential to the closed-loop control system), rotating mount, and repeater card with illumination lamps. The case is pendulous and is supported by the gimbal mounting to swing about the athwartship axis, while the gimbal ring swings about the fore-and-aft axis.



A. Repeater assembly. C. Alidade amplifier.
B. Pelorus stand. D. Telescope mount.

Figure 5-34.—Self-synchronous alidade equipment.

SYNCHRO SIGNAL AMPLIFIERS

One or more synchro signal amplifiers are used in a gyrocompass installation to increase the capacity of the transmission system. In doing this, the synchro signal amplifier performs these added functions:

1. Increases the load capacity of the small synchro transmitter in the master gyrocompass.
2. Converts its single-signal INPUT received from the master compass into both (400- and 60-cycle frequency) OUTPUT sources. The input may be either 60 or 400 cycles, only.
3. Combines both torque type and control type loads without affecting the source of the signal, which is the master gyrocompass, should one of the torque type receivers become stalled.

Three types of amplifiers, type A, E, and F are currently in use (new installations will be confined to the E and F, depending upon requirements of frequency-input versus frequency-output). These three types are similar in design, construction, and operation except for those items affected by frequency. Table 5-1 lists the input and output requirements.

Synchro signal amplifiers used with gyrocompass installations contain an amplifier unit and a mechanical unit enclosed in a single housing. The amplifier unit consists of a basic servoamplifier and associated circuits. The mechanical unit consists of synchro control transformers, a servomotor and gearing, an indicator dial to indicate own ship's course, and output synchro transmitters.

The stator outputs from the 1 or 2 speed and 36 speed synchro transmitters (fig. 5-35) on the master compass are fed to the stators of the respective CT's in the synchro signal amplifier. Error signal voltages are picked off rotors of the CT's and fed to a synchro cutover circuit. These signal voltages represent the amount of displacement (or error) between the rotors of the CT's and the transmitter rotors on the master compass.

Depending upon whether the amount of this error is large or small the cutover circuit functions to connect either the 1 or 2 speed CT signal output or the 36 speed signal output to the input of the servo amplifier. The output of the servo amplifier causes the servo motor to drive the 36 speed CT rotor through gearing to a zero signal output position or in the case of the 1 or 2 speed CT to a signal output equaling an anti-stickoff voltage (to prevent locking in on a false null). The servo motor at the same time drives the rotors of the output synchro transmitters. Thus the output synchro transmitter rotors in the synchro signal amplifier are constantly aligned with the synchro transmitter rotors on the master compass.

Feedback from the servoamplifier through a smoothing network of capacitors and resistors stabilizes the servoloop. Indicator lights on the front of the unit and an alarm bell are provided to give visual and audible indications of unit failure or malfunction. Power for the indicator lights and alarm bell is supplied via relays in the relay signaling circuit.

MAINTENANCE AND TROUBLESHOOTING

Monthly checks of alarm circuits and a yearly accuracy and gearing inspection are necessary. Alarm circuits should be checked by following the detailed steps recommended for the installation on your ship. This check, generally. requires you to energize the equipment which supplies voltage to the compass installation; to

Table 5-1.—Synchro Signal Amplifiers—Input and Output Requirements.

Type Amplifier	Input Frequency	Input Speed	Output Frequency	Output Speed
A	60	1 or 2	60	1 or 2
	60	36	60	36
E	60	1 or 2	60	1 or 2
	60	36	60	36
		1 or 2	400	1 or 2
		36	400	36
F	400	1 or 2	60	1 or 2
	400	36	60	36
			400	1 or 2
			400	36

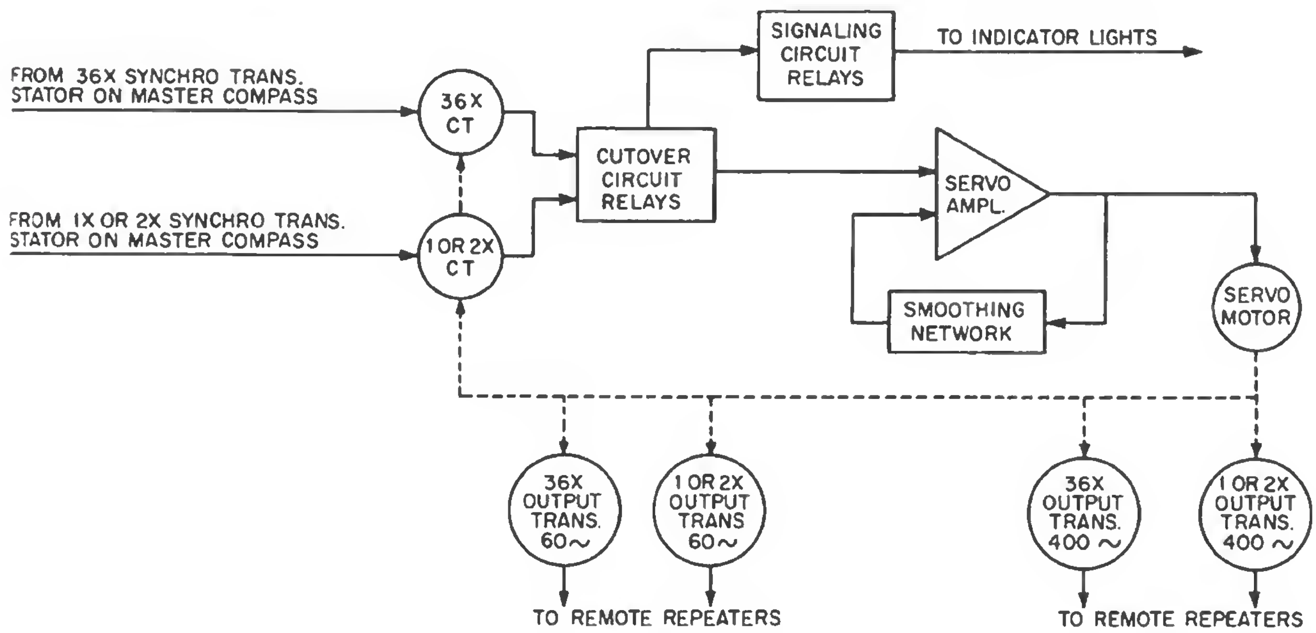


Figure 5-35.—Block diagram of type "F" synchro signal amplifier. 40.53

turn the alarm system to ON; and then to displace the test knob (on specified gearing) that is provided, and note whether the deenergized relay causes its alarm to function. Next, deenergize each of the output supply circuits one at a time. The alarm should sound each time.

Inspect all gearing during the annual inspection. If dirt is found, clean the gears. If a gear shows excessive wear, replace it. Turn the gears manually, with the equipment deenergized as instructed in its equipment manual. Lightly apply instrument grease to the gearing in accordance with MIL-G-1506.

The yearly accuracy check covers the performance of individual amplifiers by comparing the dial readings at the input with those at the output repeater. If the dial readings disagree by more than 0.1°, trouble is present. Check alignment of individual units as directed in the manufacturers' manual. Always remember that those specific instructions supersede the brief general instructions found elsewhere.

The alarm system is arranged with alarm bell and lights to assist in locating troubles quickly. Study manufacturers' technical manuals thoroughly to become familiar with the equipment so as to reduce troubleshooting time to an absolute minimum.

QUARTERLY INSPECTIONS-GYROCOMPASS INSTALLATIONS

"Every gyrocompass and gyrostabilizer installation, including all subsidiary equipment, apparatus, appurtenances, and repair parts, shall be inspected once each quarter by a qualified person, and suitable entries made by that person in the Service Record Book."

The above extract is made from Bureau of Ships Technical Manual, Chapter 24. It is applicable for every gyroscope installation, regardless of other periodic inspections which are given in equipment technical manuals.

Quarterly inspections are necessary and important to the gyrocompass operation to discover any deterioration of the compass equipment and to alert the operator to possible weaknesses or oversights in the preventive maintenance program.

Shortage of qualified inspectors makes it necessary to permit qualified gyrocompass operators to make their own inspections. Graduates of IC "B" and "C" schools are qualified to make their own inspections. However, this

does not mean the suspension of requests for inspections when undergoing yard overhaul or alongside tenders or repair ships; nor does it revoke the right of the cognizant officers for making inspection of gyrocompass equipment aboard ships of their respective forces.

CHAPTER 6

GYROCOMPASSES (PART II)

SPERRY MK 19 MOD 3 GYROCOMPASS

The Mk 19 Mod 3 gyrocompass is a navigational and fire control instrument with design features based on unusual requirements. The compass is designed to operate in latitudes up to 80° with an accuracy in heading of .1 of one degree. In addition it accurately measures and transmits angles of roll and pitch. This feature distinguishes the Mk 19 Mod 3 from all other shipboard gyrocompasses in use at the present time.

Design of the compass is based on the principle that two properly controlled horizontal gyros can, together, furnish a stable reference for the measurement of ship's heading, roll, and pitch. Briefly, the basic unit consists of two gyros placed with their spin axes as shown by figure 6-1. The top gyro is a conventional gyrocompass and is referred to as the north-seeking, or meridian gyro. Its spin axis is directed along a north-south line and it furnishes indications of ship's heading, roll (on east-west courses) and pitch, (on north-south courses). The lower gyro is a directional gyro with its spin axis slaved to the meridian gyro along an east-west line. It is referred to as the slave gyro and furnishes indications of roll on north-south courses, and pitch on east-west courses.

An electronic control system is used in the Mk 19 Mod 3 gyrocompass to make it seek and indicate true north as well as the zenith. A gravity reference system is employed for detecting gyro tilt, and torques are applied electromagnetically (as described in I.C. Electrician 2, NavPers 10556-A for the Mk 23 Mod 0 compass) to give the meridian gyro the desired period and damping. Further, signals are generated by the compass, which are used to stabilize the entire sensitive element in roll and pitch, thereby furnishing an indication of the zenith in terms of roll and pitch data.

Both the meridian and slave gyros are enclosed in hermetically sealed spheres and

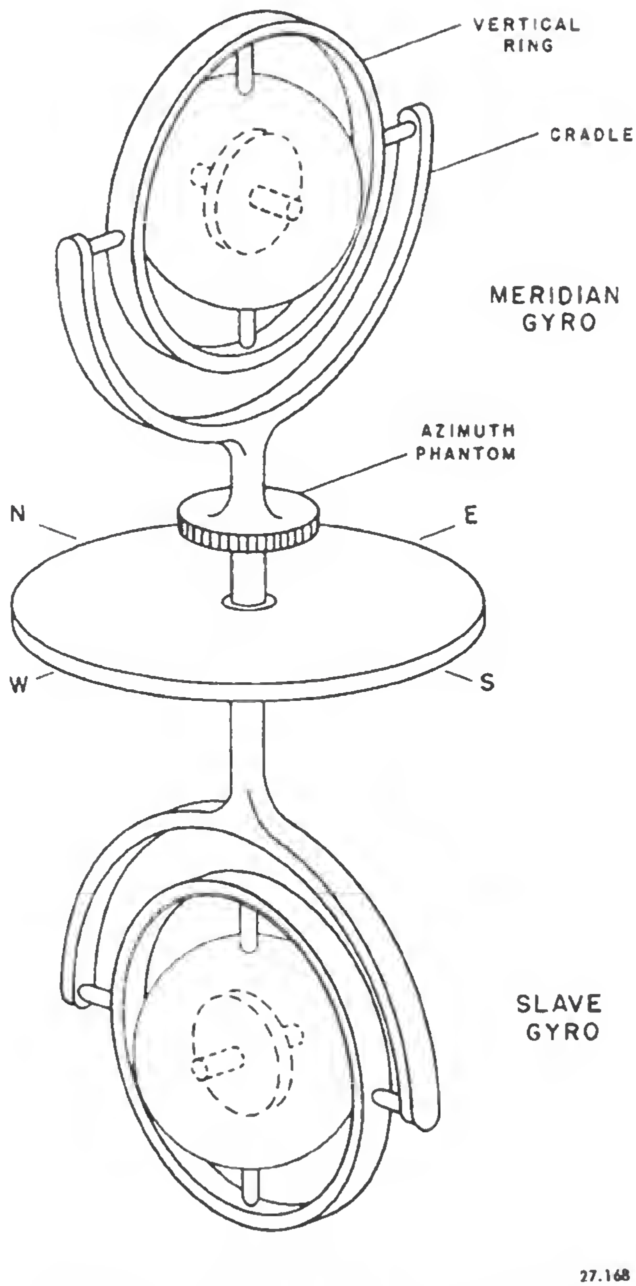


Figure 6-1.—Simplified diagram of the Mk 19 Mod 3 compass element.

suspended in oil. The compass is compensated for northerly and easterly speed and acceleration, earth rate, constant torques, and followup errors. The system (fig. 6-2) consists of four major components; the master compass, control cabinet, compass failure annunciator, and the standby supply.

MASTER COMPASS

The master compass (fig. 6-3) is approximately 3 feet high and weighs about 510 pounds. Its two major portions are the compass element and the supporting element.

Compass Element

The compass element includes the sensitive element (meridian and slave gyros) the gimbal and the phantom assembly. The phantom assembly includes the azimuth phantom, which defines the meridian, and the roll and pitch phantom, which defines the zenith.

Supporting Element

The supporting element includes the frame, and binnacle. The compass elements are gimbaled in the binnacle by a conventional gimbaling system, with $\pm$ 60 degrees of freedom about the roll axis and $\pm$ 40 degrees about the pitch axis.

The meridian and slave gyros are similar in construction with the exception that the gravity reference is inverted in the slave gyro and minor changes in wiring are made. The two gyro assemblies are mounted on the inner ring of the phantom assembly, the meridian gyro on top, and the slave gyro, upside down, to the under side. The gyro motors are 2-pole, 115-volt, 3-phase, 400-cycle squirrel cage induction motors. The meridian gyro rotates approximately 23,600 rpm clockwise viewed from the south, and the slave gyro rotates at the same speed counterclockwise viewed from the east.

The azimuth phantom is made to follow the azimuth motion of the meridian gyro and 1- and 36-speed heading data are transmitted by means of the azimuth servo and synchro assemblies mounted on the phantom assembly. The roll and pitch phantom is stabilized in roll and pitch, and 2- and 36-speed roll and pitch data are transmitted by means of the roll and pitch servo and synchro assemblies mounted on the frame and binnacle.

CONTROL CABINET

The control cabinet (fig. 6-2) contains the d-c power supply, computers, amplifiers, and other assemblies required for operating and indicating the condition of the gyrocompass system. The cabinet is composed of the control panel, computer indicator panel, computer control assembly, system control assembly, followup amplifiers, and the d-c power supply.

Control Panel

The control panel (fig. 6-4) contains all the switches, alarm lamps, and indicator fuses required for operating the system. Only the controls required for normal operation of the system are accessible when the control cabinet is closed. These controls are on a recessed panel to avoid injury to personnel, damage to the controls, or accidental change of setting.

Computer Indicator Panel

Below the control panel, inside the cabinet, are located seven computer assemblies for computing data for the system. The computer indicators are viewed through seven flush windows in the front of the cabinet (fig. 6-5). These assemblies are discussed later under the control system in which they are used.

Computer Control Assembly

To minimize the number of different kinds of amplifiers used in the system, two types of standard plug-in computer amplifiers are used in 13 applications. As the characteristics and the circuits in which the amplifiers are used vary, other components peculiar to a single circuit must be used. For this reason, a T-shaped panel, called the computer control assembly, is located inside the control cabinet. This panel provides a junction box into which the amplifiers may be plugged, and serves as a chassis for the various components required to match the standard amplifiers to the particular circuits concerned. The computer control assembly houses 11 type 1, and 2 type 2 general purpose computer amplifiers, and contains all the components required for operation of the various computer and torquer circuits, other than those contained in the mechanical assemblies, or in the master compass.

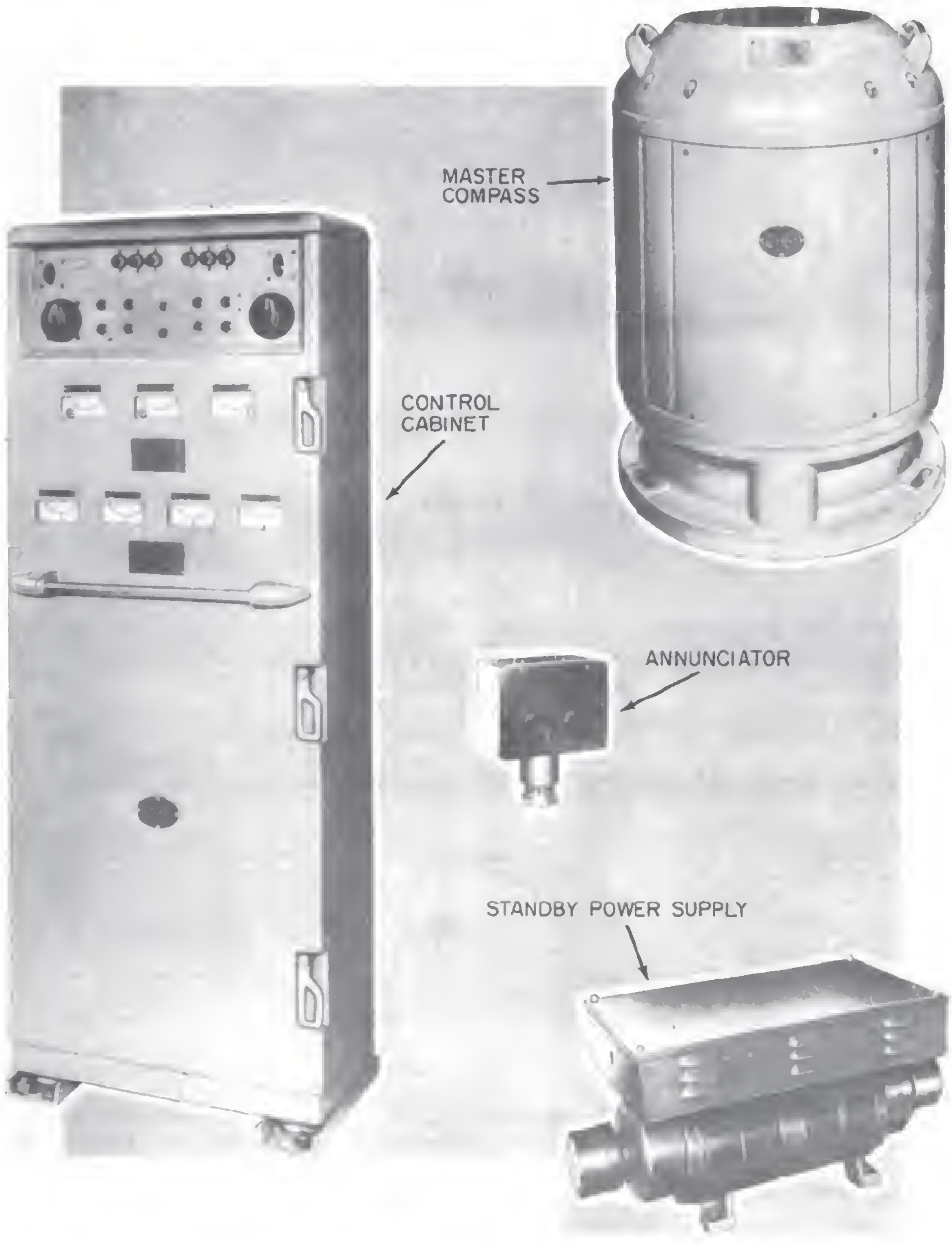


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Figure 6-2.—Mk 19 Mod 3 gyrocompass equipment.

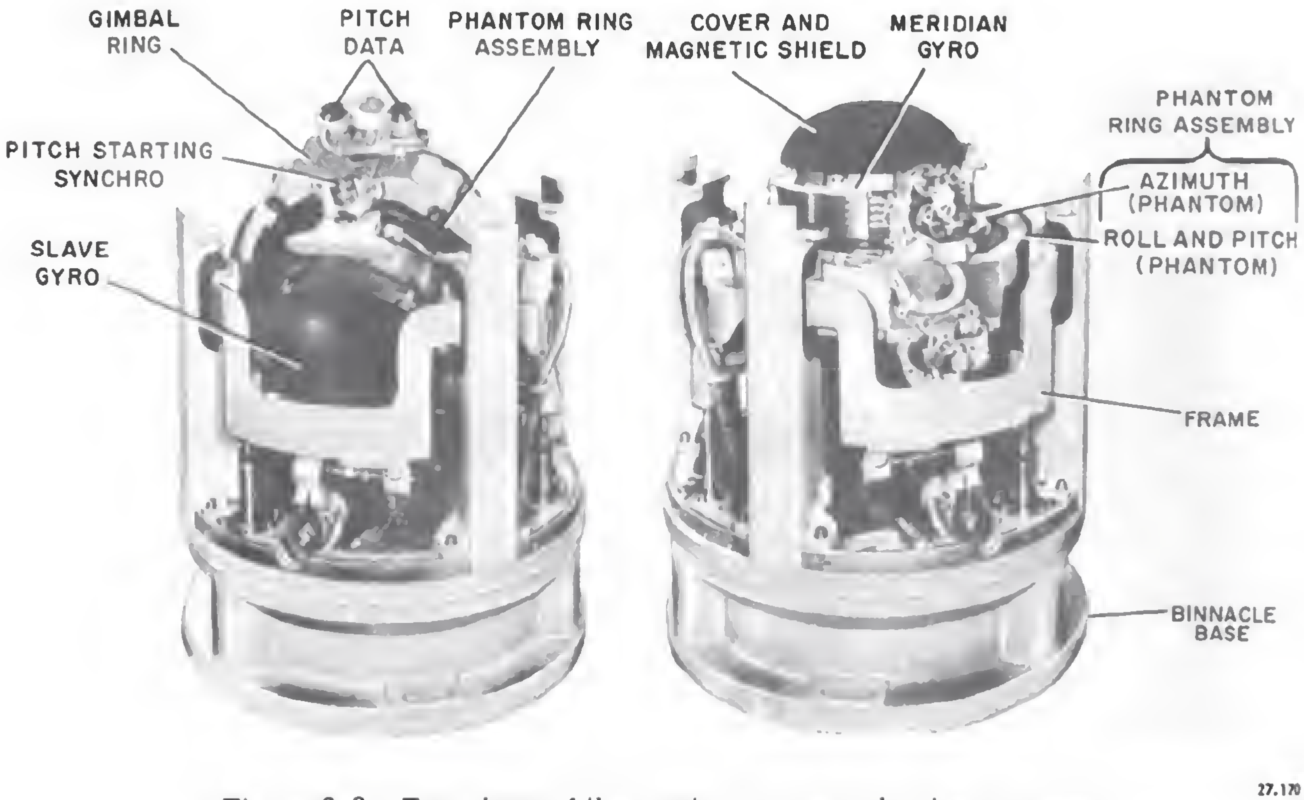

Figure 6-3.—Two views of the master compass showing compass element and supporting element.

System Control Assembly

The system control assembly (fig. 6-6) is mounted at the top of the rear section of the control cabinet and includes switches, relays time delay circuits, and auxiliary devices for cycling the events automatically, as required for starting and operating the compass system. These components operate in conjunction with the switches, indicators, and relays on the control panel (fig. 6-4) and elsewhere in the system, in performing starting and control functions.

Followup Amplifiers

Mounted below the system control assembly are the roll, pitch, and azimuth followup amplifiers. The three followup amplifiers are identical and interchangeable.

D-c Power Supply

Below the followup amplifiers is the d-c power supply unit (fig. 6-7A) containing the power supply components (metallic rectifiers, filters and so forth), a monitoring meter, and associated selector switch. The unit operates from the 115-volt, 400-cycle, 3-phase supply and furnishes all d-c voltages required for the operation of the various amplifiers and relays in the system.

As a supply voltage fluctuation even as low as 2 volts can cause compass errors, a voltage regulator was developed for the Mk 19 Mod 3 system. This regulator is designed to be installed in the bottom of the control cabinet and provides an output of 115 volts 400 cycle a-c regulated within $\pm$.75 volt for an input of 115 volts $\pm$7 volts. The regulator unit (fig. 6-7B) is a single chassis containing a diode rectifier circuit, a d-c reference circuit, a differential amplifier, and a corrector circuit. The corrector circuit includes a magnetic amplifier, a servomotor and gear train, a variable autotransformer and a buck-boost transformer.

An alarm indicator lamp is provided to indicate servo unbalance, tube heater failure, and excessive input voltage. In addition, the unit contains a magnetic amplifier balance

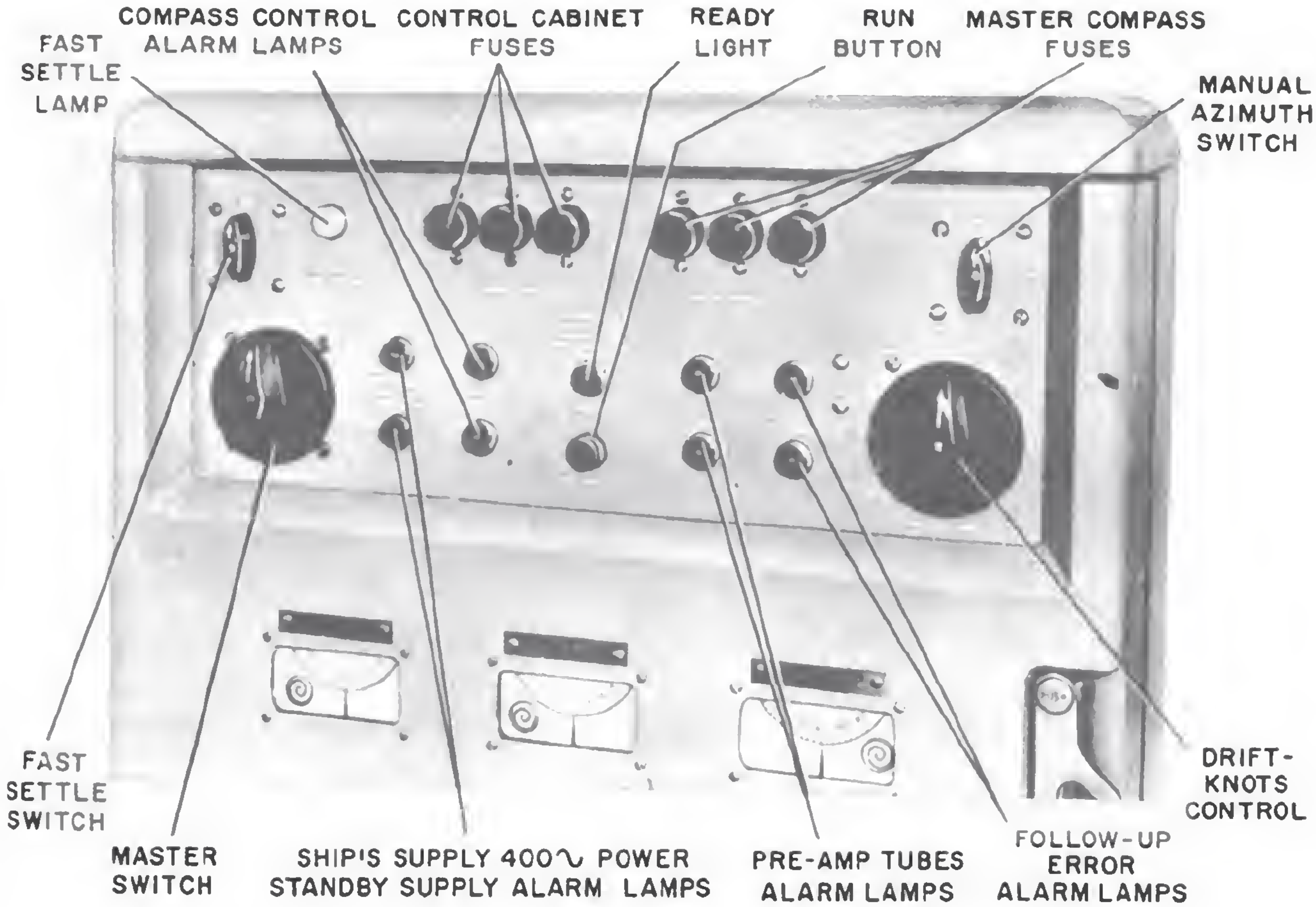

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Figure 6-4.—Control panel.

control, a nominal voltage adjustment control, an auto-manual switch and an a-c voltmeter to indicate the regulated output voltage.

In addition to these components and assemblies, the control cabinet also includes an isolation transformer, a ventilating fan, and spare amplifier.

The isolation transformer is located immediately below the top of the rear portion of the control cabinet and isolates the compass system from the rest of the components connected to the ship's 400-cycle power mains, thus eliminating line-to-ground potentials from the ship's 400-cycle system.

The ventilating fan is located above the isolation transformer and provides ventilation for the interior of the cabinet. The fan motor is identical to the servomotors used in the followup circuits and may be used as a spare in an emergency.

At the bottom of the rear portion of the control cabinet is a spare, type 1 computer amplifier.

COMPASS FAILURE ANNUNCIATOR

The compass failure annunciator (fig. 6-2) is a remote visual indicator, of the same type used in the Mk 23 system. Associated with the annunciator is usually a Navy standard type B-10 alarm bell. The alarm bell and annunciator are actuated by the alarm control system to give both a visual and audible indication of system failure. The compass alarm system is discussed later in this chapter.

STANDBY SUPPLY

The standby supply (fig. 6-2) is a motor-generator set which provides emergency power for the compass system, for a short time, in

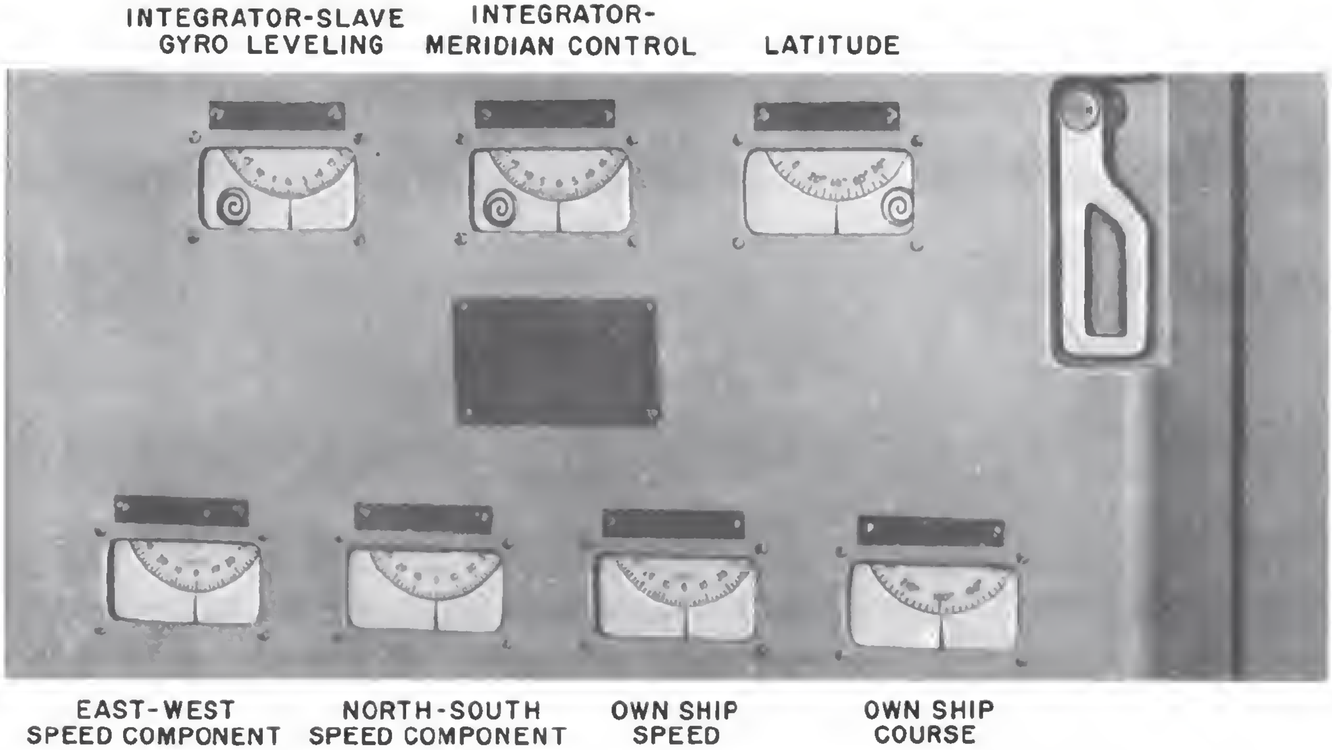

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Figure 6-5.—Computer indicators.

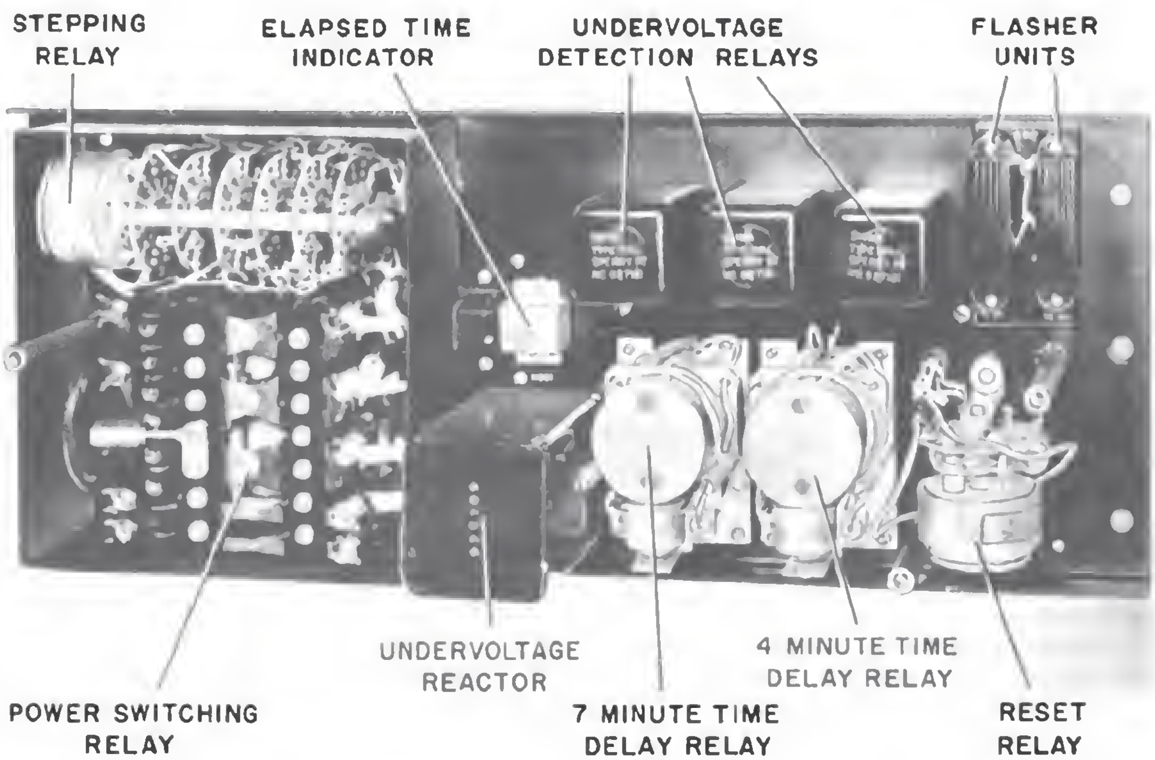

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Figure 6-6.—System control assembly.

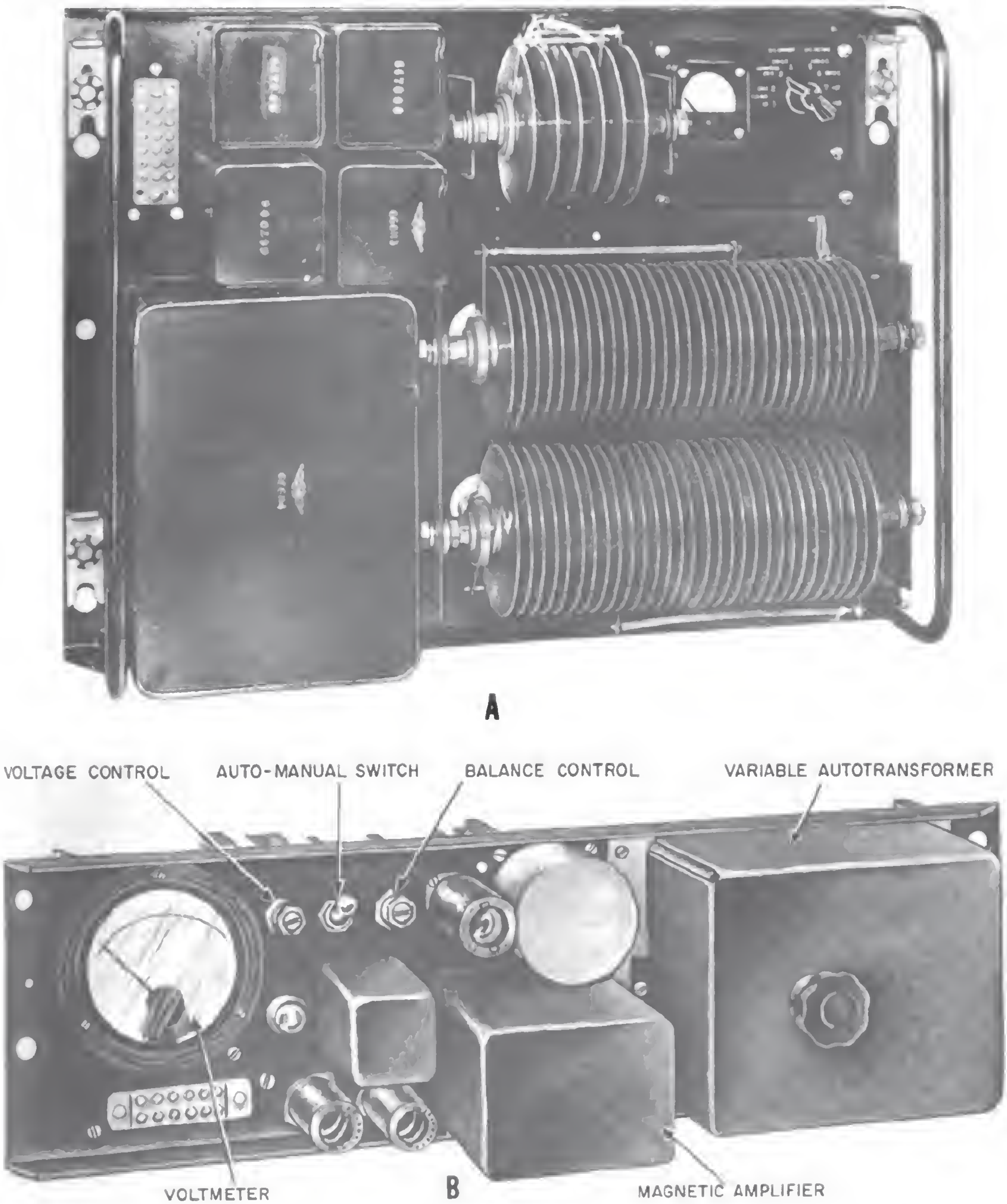

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Figure 6-7.—A. Power supply. B. Mk 19 voltage regulator.

case of failure of the ship's power supply. Under normal operation the a-c section operates as a 115-volt, 400-cycle, 3-phase synchronous motor, driving a 120-volt compound wound d-c generator, that charges a bank of twenty 6-volt storage batteries. If the ship's 400-cycle supply fails, or falls below 102 volts, the ship's line is disconnected automatically and the 120-volt d-c generator is driven, as a motor, by the storage batteries. The a-c section now operates as a 115-volt, 400-cycle, 3-phase generator supplying the compass system.

MK 19 MOD 3 GYROCOMPASS CONTROLS

All controls for the Mk 19 Mod 3 gyrocompass system (fig. 6-8A and B) are contained in four major systems, the meridian gyro control system, slave gyro control system, the azimuth followup system, and the roll and pitch followup system.

MERIDIAN GYRO CONTROL SYSTEM

The meridian gyro control system includes the gravity reference system, the azimuth control system, and the leveling control system. These systems are similar to, and function to control the meridian gyro in the same manner as the Mk 23 compass control system. The compass compensation system is more elaborate, however, due to the high degree of accuracy required of the Mk 19 Mod 3 gyrocompass, and will be discussed separately.

Meridian Gyro Gravity Reference System

The gravity reference system (fig. 6-8A) consists of the meridian gyro gravity reference (the electrolytic bubble level and excitation transformer), the north-south acceleration computer, a mixer and its associated network.

The tilt signal from the electrolytic bubble level is fed into the mixer, which contains a step-up transformer and a cathode follower. Here, the tilt signal is mixed with the north-south acceleration signal (a compensation signal to be discussed later), and the compensated tilt signal is fed into a network of resistors, potentiometers, and relay contacts. The network has three output signals: the meridian control signal to the azimuth control system, the damping signal to the leveling control system, and the compensated tilt signal to the meridian gyro constant torque compensation system.

Meridian Gyro Azimuth Control System

The azimuth control system consists of a mixer, an azimuth torquer amplifier, and the azimuth torquers. The mixer contains a step-up transformer, potentiometers and resistors. The azimuth torquer amplifier is a general purpose type 1 computer amplifier, which contains two double-purpose twin triodes (fig. 6-9). The input stage uses one-half of one tube, the other half being used in the compass alarm circuit. The output stage uses both halves of its tube in a push-pull circuit. The mixer input signals are the meridian control signal from the gravity reference system, an east-west speed signal, a constant torque signal, and a vertical earth rate compensation signal. The azimuth torquer amplifier output is fed to the control fields of the two azimuth torquers which apply torque to precess the meridian gyro toward the meridian, in the same manner as described in the Mk 23 system.

Meridian Gyro Leveling Control System

The meridian gyro leveling control system (fig. 6-8A) consists of a mixer, which includes a step-up transformer, a potentiometer and resistors, the leveling control amplifier (another type 1 computer amplifier), and the leveling torquer. The input signals to the mixer are the damping signal from the gravity reference system, and the north-south speed plus drift compensation signal. The amplifier output supplies the leveling torquer control field, which produces the torque to level the meridian gyro.

SLAVE GYRO CONTROL SYSTEM

The slave gyro control system (fig. 6-8A) consists of the slave gyro gravity reference system, leveling control system, and slaving control system.

Slave Gyro Gravity Reference System

The slave gyro gravity reference system is similar to the meridian gyro gravity reference system. It consists of a gravity reference, a mixer and its network, and the east-west acceleration computer. The output of the system is the slave gyro amplified and compensated tilt signal, which is fed to the slave gyro leveling control system, and the slave gyro constant torque compensation system.

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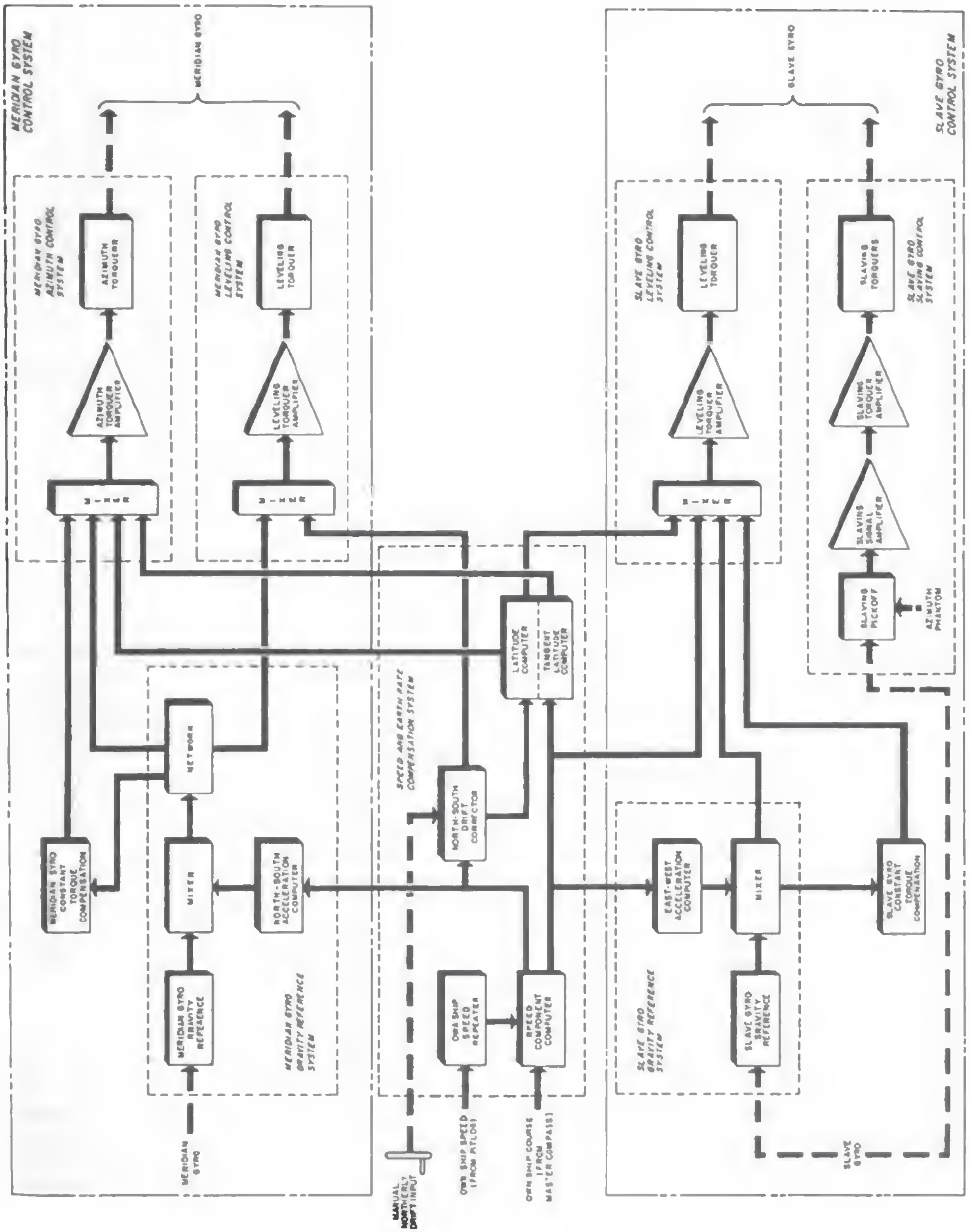

Figure 6-8A.—Block diagram of complete compass control system.

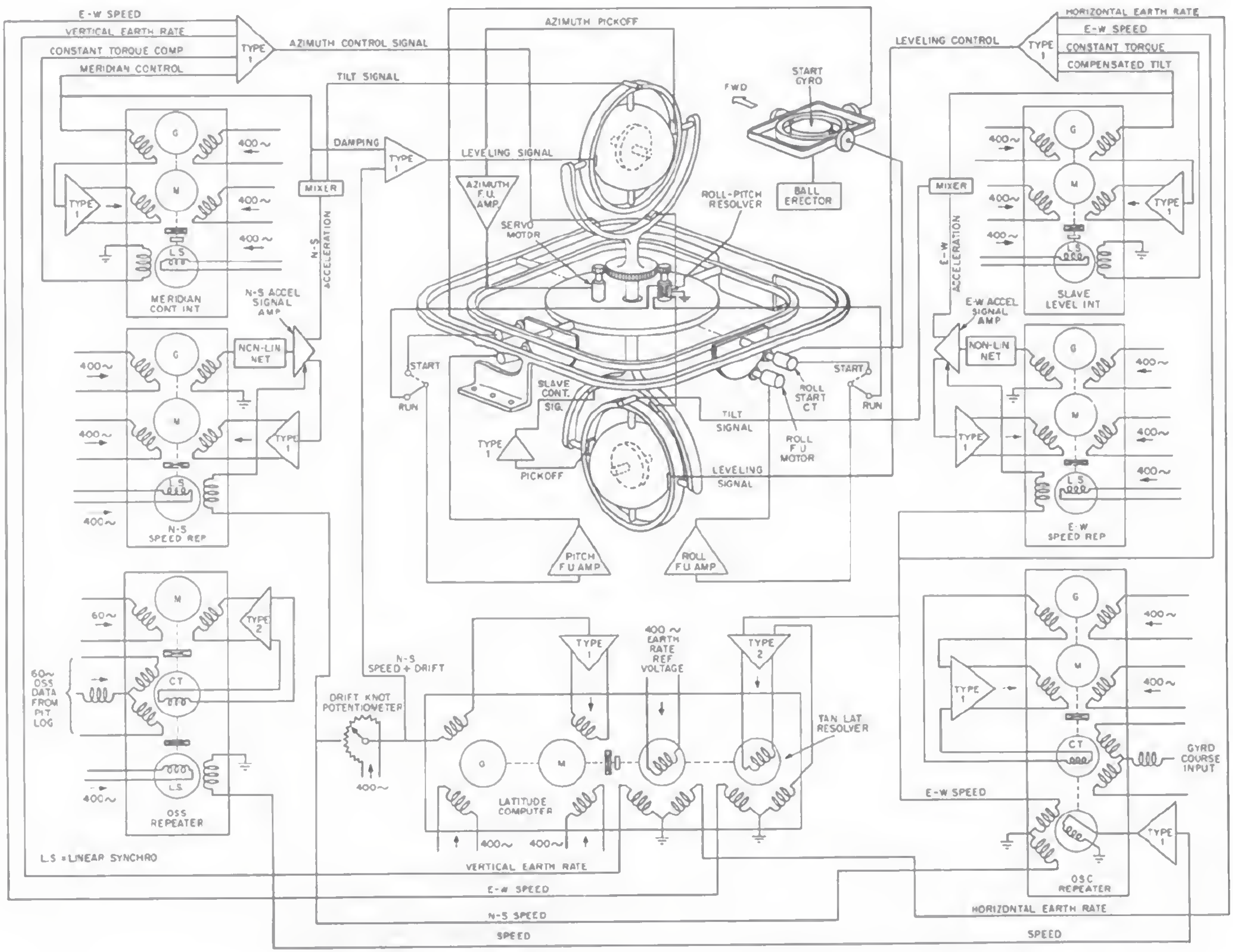

Figure 6-8B.—Simplified schematic diagram of complete compass control system.

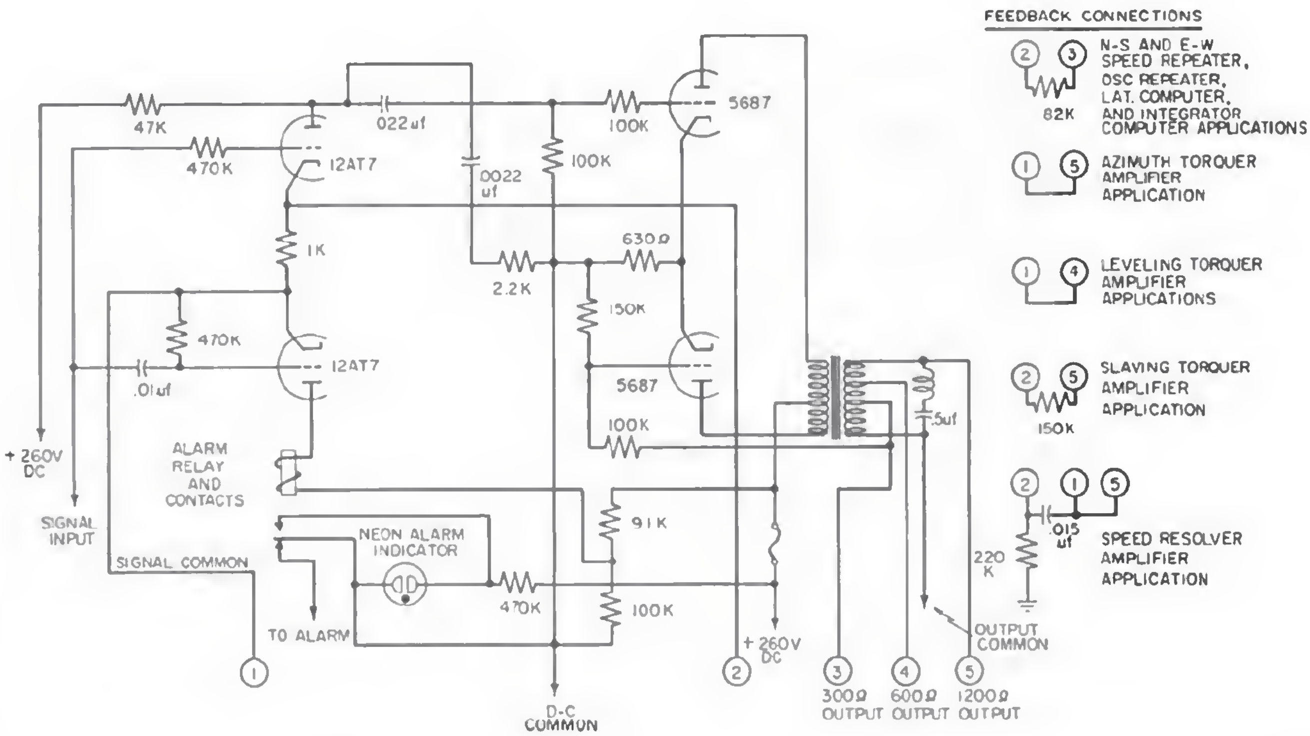

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Figure 6-9.—Simplified schematic diagram of type 1 computer amplifier.

Slave Gyro Leveling Control System

The slave gyro leveling control system consists of a mixer, a leveling torquer amplifier, and a leveling torquer. The input signals to the mixer are the compensated tilt signal from the slave gyro gravity reference system, and horizontal earth rate, east-west speed, and constant torque, compensation signals. The leveling torquer amplifier and leveling torquer are duplicates of those used in the meridian gyro leveling control system. The output of the leveling torquer amplifier to the leveling torquer control field is the slave gyro leveling control signal.

Slave Gyro Slaving Control System

The slaving control system detects any misalignment between the azimuth phantom and the slave gyro, and slaves the gyro to its proper east-west position. The system consists of the slaving pickoff, slaving signal amplifier, slaving torquer amplifier, and two slaving torquers. The slaving pickoff is an E-core transformer mounted on the vertial ring. The armature of the pickoff is cemented to the gyrosphere. Thus a misalignment signal between the azimuth phantom and the slave gyro is obtained from the pickoff in the same manner as described in the Mk 23 system. This signal is fed into the slaving signal amplifier which contains a step-up transformer and cathode follower. The output of the slaving signal amplifier is the slaving signal, and it is fed to the slaving torquer amplifier, a type 1 computer amplifier. The output of the slaving torquer amplifier is the slaving control signal, and it is fed to the slaving torquer control fields.

The slaving torquers are duplicates of the azimuth torquers, and operate in the same manner. They produce the torque about the slave gyro horizontal axis, which causes precession about the vertical axis, to align the azimuth phantom and slave gyro.

COMPENSATION SIGNALS

There are nine compensation signals in the Mk 19 Mod 3 gyrocompass system. These signals serve to counteract or compensate for certain effects that would otherwise produce

azimuth or leveling errors in the master compass.

These effects may be classified as ship effects, which include speed, course, and acceleration; earth effects, which include horizontal and vertical earth rate; and constant torque effects, which may be caused by mechanical unbalance of the master compass; or any other mechanical defects that would cause the compass to settle with a tilt.

As discussed in the previous chapter, northerly or southerly ship speed produces a gyrocompass error due to gyro tilt as the ship follows the curvature of the earth. The rate of this gyro tilt is proportional to the product of ship's speed S, and the cosine of own ship's course C. Easterly speed, however, produces an error equal to the product of ship's speed S. and the sine of own ship's course C. Easterly or westerly speed does not cause the meridian gyro to tilt; however, as the slave gyro is aligned east-west it is affected by easterly or westerly speed in the same manner as northerly or southerly speed affects the meridian gyro. The Mk 19 compass is compensated for speed errors by applying a compensation signal equal to S cos C to the meridian gyro leveling control system, and a signal equal to S sine C, to the slave gyro leveling control system. Thus both gyros are maintained in a level position for any speed or course. These signals are obtained from the own ship speed repeater and speed component computer shown in the block diagram (fig. 6-10).

The own ship speed repeater operates on 60 cycle data obtained from the ship's pitometer log transmitter. The output of the repeater, however, is 400 cycle data. The repeater contains a 60-cycle servomotor, B1, a 60-cycle synchro control transformer, B2, a 400-cycle linear synchro, B3, and dial, and a type 2 computer amplifier.

The linear synchro is an induction device like other synchros, but differs from other types in that is has one input rotor winding, and one center-tapped output stator winding which produces an output voltage that is a linear function of its rotor position. The rotor winding is excited from the 400-cycle supply. When the rotor is in such a position that the axes of the two windings are separated by 90 electrical degrees, no voltage is induced in the output stator winding. If the rotor is displaced in one direction from this zero voltage position, a voltage is induced in the output winding that is proportional to the amount of rotor displacement. If the rotor is displaced in the opposite direction, a voltage of opposite phase is induced in the output winding, that is also proportional to the amount of rotor displacement.

The 60-cycle servomotor is a 2-phase 2-pole induction motor, with a fixed field excited from the 60-cycle power line, and control field connected to the type 2 computer amplifier output.

The type 2 computer amplifier (fig. 6-11) is similar to the type 1 in that its input stage uses one half of a double triode, and the other half is used in the compass alarm circuit. The output stage, however, uses a pentode.

The input to the repeater is the own ship's speed from the pitometer log to the control transformer, B2 (fig. 6-10). The output signal voltage from the control transformer representing ship's speed, is fed to the input of the type 2 computer amplifier. The servomotor, B1, drives the control transformer rotor to its null position, and at the same time positions the linear synchro rotor, B3, to a position corresponding to ship's speed. The linear synchro output, then, is a 400-cycle voltage proportional to own ship's speed. A dial is attached to the shaft of the linear synchro to provide a visual indication of own ship's speed.

The own ship's speed signal is applied to the input stage of a type 1 computer amplifier in the speed component computer. The speed component computer also contains another type 1 computer amplifier, and an own ship's course repeater consisting of a speed resolver, B4, and dial, a synchro control transformer, B5, and motor-tachometer B6.

The motor-tachometer is a 400-cycle servomotor tachometer generator built into the same housing. The motor is a 2-phase, 4-pole induction motor with a fixed field and a control field. The tachometer generator section consists of a 2-phase, 2-pole stator and a copper shell rotor. One stator field is excited from the 115-volt, 400-cycle supply. The other stator field is not excited as long as the rotor is stationary (the axes of the two stator windings are 90° apart). When the shaft of the rotor is turned a voltage is induced in the rotor, and rotor current flow is proportional to rotor speed. This rotor current produces an mmf proportional to rotor current. This mmf is combined with the mmf of the reference winding to produce a resultant field, the axis of which is displaced in the direction of rotation of the

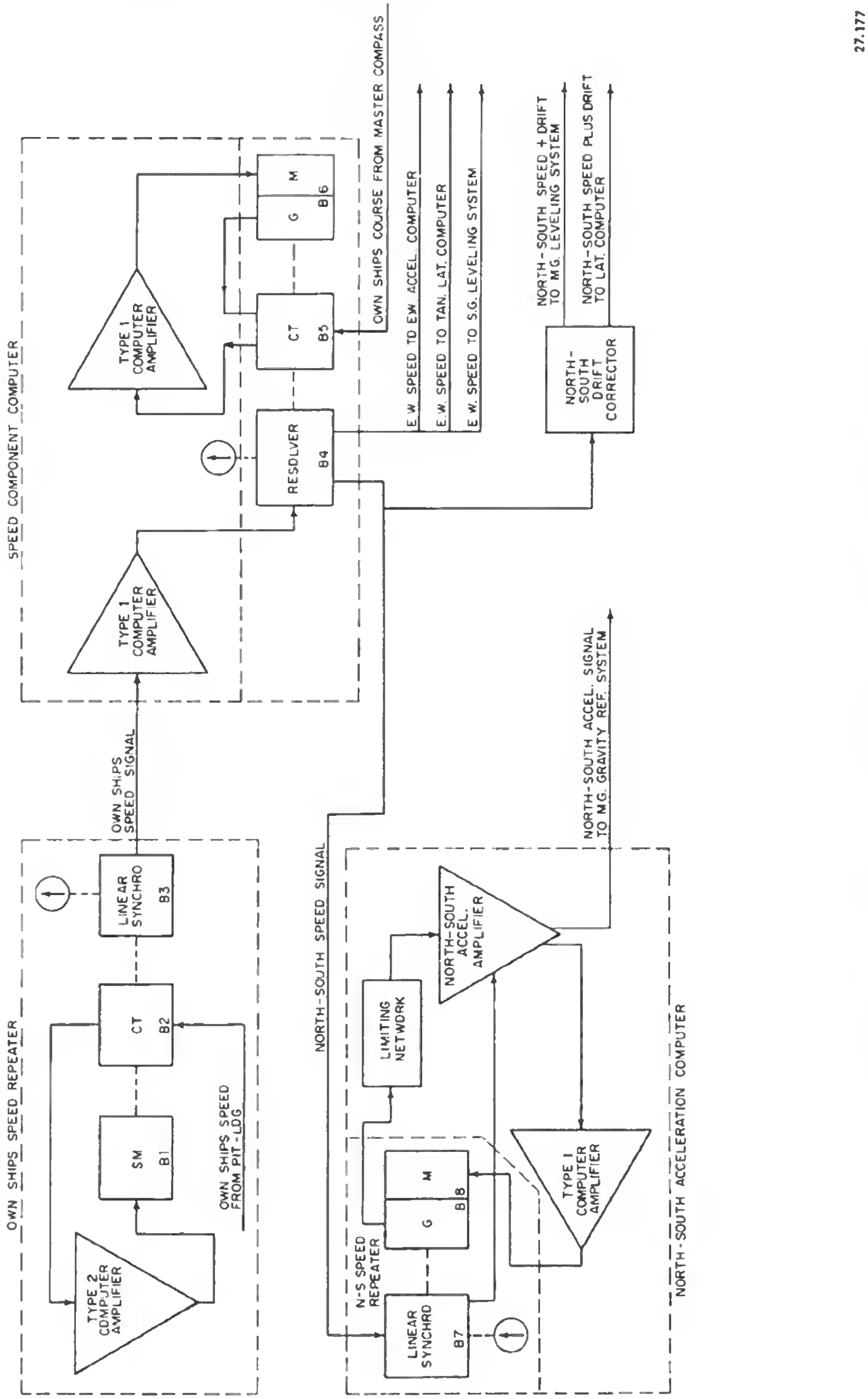

Figure 6-10.—Speed, course, and acceleration compensation signals.

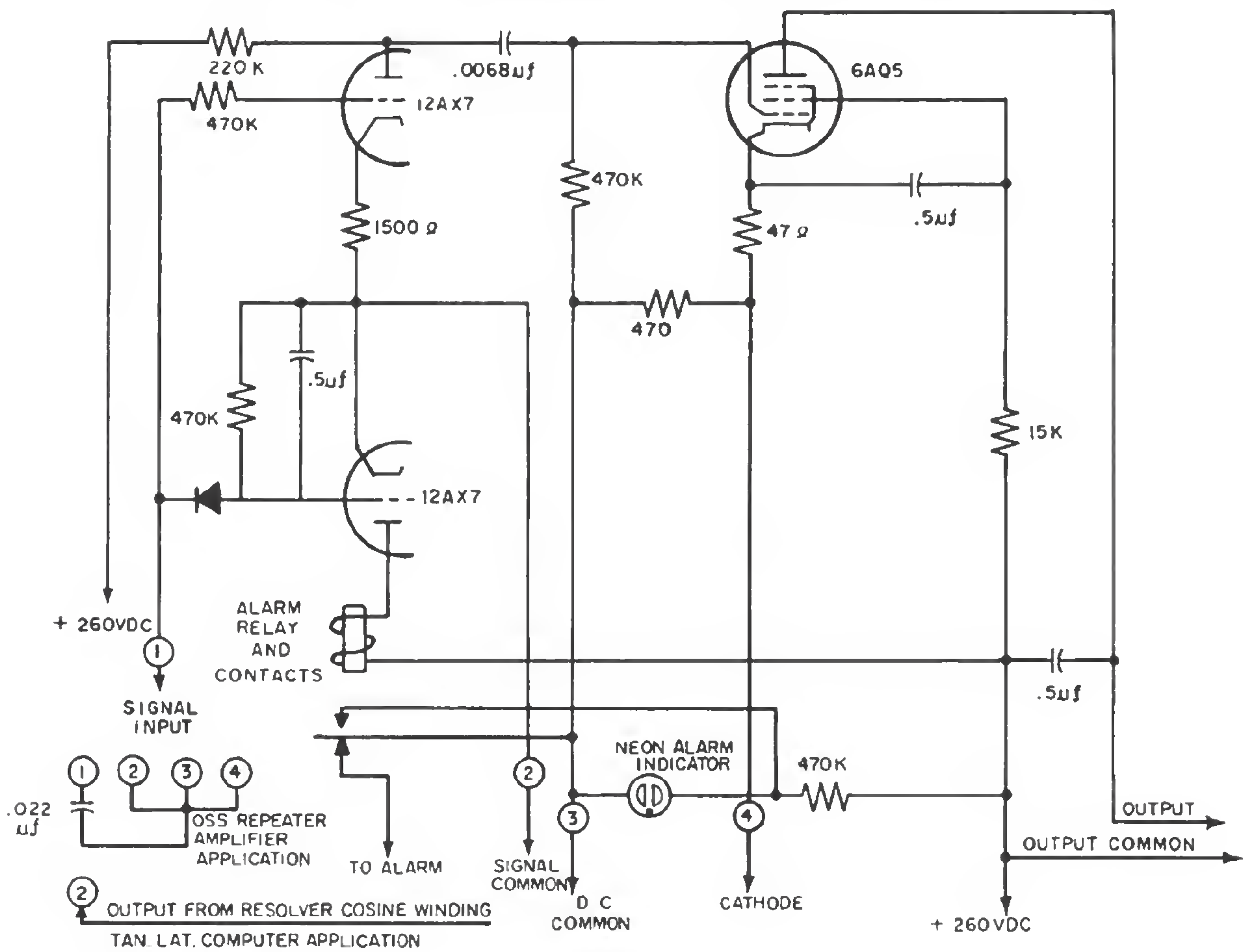

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Figure 6-11.—Simplified schematic diagram of type 2 computer amplifier.

rotor cup. The angle between the resultant field axis and the axis of the output winding varies with the speed. Hence the coupling between the two stator windings varies with the speed. Thus the output voltage varies with the speed. Its frequency is 400 cycles, the same as that of the reference field and the phase of the output voltage is dependent upon the direction of rotation of the rotor cup.

The own ship speed signal is amplified and fed to the rotor winding of speed resolver B4. Heading data from the master compass is applied to the input of control transformer B5, and the output of B5 in series with a damping voltage obtained from the generator section of motor tachometer B6 is fed to the input of the second type 1 computer amplifier. The damping signal voltage from the motor tachometer is used to stabilize the computer servo loop and to introduce a small time lag in the computer. This time lag is required since the direction of motion of the ship's center of gravity differs from the ship's heading for a short interval after starting a course change. In other words, when rudder is first applied to turn the ship, the ship slides sidewise to some extent so that the original course is maintained for a short interval even though the ship's heading has changed.

The output of the second type 1 computer amplifier excites the control field of the motor section of the motor tachometer, B6, which drives the tachometer generator section, furnishing the damping signal voltage, and at the same time the control transformer rotor of resolver B4 is positioned relative to the ship's

heading. Resolver B4 functions to resolve own ship's speed and course inputs into S cos C or north-south speed and S sin C or east-west speed. These are the speed compensation signals needed. A dial is coupled to the shaft of resolver B4 indicating own ship's course.

As the ship's heading and course may differ due to north-south drift, the north-south speed signal is compensated for drift by a manual corrector located on the front of the control cabinet. This drift setting is made by the compass operator after obtaining the necessary information from the ship's navigator.

If the ship accelerates in speed, the inertia will displace the electrolyte in the electrolytic bubble level. Deceleration will cause a displacement in the opposite direction. As a result, tilt signals will be produced even though there is no gyro tilt, and compass errors will result if not compensated for.

Acceleration compensation is obtained for the meridian gyro by the north-south acceleration computer, and for the slave gyro by the east-west acceleration computer.

The north-south acceleration computer (fig. 6-10) contains a north-south speed repeater consisting of a linear synchro and dial B7, and a motor-tachometer B8. The computer also includes a limiting or nonlinear network, a north-south acceleration signal amplifier, and a type 1 computer amplifier.

The north-south speed signal voltage is fed to the stator of linear synchro B7, in series opposition with the stator voltage induced by the synchro rotor. The difference between these two voltages is applied in series with the north-south acceleration signal amplifier output, to the input of the type 1 computer amplifier. The output of the type 1 computer amplifier drives the motor section of the motor tachometer, B8, at a speed proportional to the rate of change of the ship's north-south speed, and positions the rotor of linear synchro B7 until the stator voltage due to rotor position equals the north-south speed signal voltage. A voltage proportional to the rate of change of the ship's north-south speed is obtained from the generator section of motor tachometer B8, and applied through a limiting network to the input of the north-south acceleration signal amplifier, whose output is the north-south acceleration compensation signal to the meridian gyro gravity reference system. When the electrolytic bubble is displaced due to accelerations, it starts to return rapidly at first to its neutral position, then slows down. This is due to the viscosity of the electrolyte and the design of the level. By connecting the acceleration signal in series with the linear synchro before applying the voltage to the motor, of the motor tachometer, the motor speed is made to vary nonlinearly. This nonlinear speed is designed to be proportional to the output of the electrolytic bubble level. In addition, the output signal voltage from the electrolytic bubble level is proportional to the displacement of the bubble over a limited range, beyond which it saturates. If the accelerations are of sufficient magnitude, the electrolytic bubble level will saturate. This factor is also compensated for by applying the output of the tachometer generator to a limiting network of rectifiers. The output of this network is amplified and used as the tachometer feedback voltage to the input of the type 1 computer amplifier.

A dial is attached to the shaft of linear synchro B7, indicating the north-south component of own ship's speed.

The east-west acceleration computer contains similar components and operates in the same manner as the north-south acceleration computer. Its input is east-west speed from the speed component computer and its output is the east-west acceleration compensation signal to the slave gyro gravity reference system.

The effect of vertical earth rate on the meridian gyro is proportional to the product of earth rate and the sine of the ship's latitude. The effect of horizontal earth rate on the slave gyro is proportional to the product of earth rate and the consine of the ship's latitude. As the effect of vertical earth rate is caused by the speed of the earth's rotation about its north-south axis, a ship traveling in an easterly or westerly direction will either add to or subtract from the earth's rotation. This apparent change in the speed of the earth's rotation will, in effect, produce a comparable change in vertical earth rate. This change in vertical earth rate is proportional to the product of the ship's east-west speed and the tangent of the ship's latitude.

To compensate for these earth effects on the meridian gyro, we need a compensating signal voltage proportional to the product of earth rate and the sine of the ship's latitude, and a compensating signal voltage proportional to the product of east-west speed and the tangent of the ship's latitude.

To compensate the slave gyro for the effect of horizontal earth rate, we need a compensating signal voltage proportional to the product of earth rate and the cosine of the ship's latitude. These compensating signals are obtained from the latitude and tangent latitude computers (fig. 6-12).

The latitude computer, which produces the horizontal and vertical earth rate compensation signals, consists of a type 1 computer amplifier, a motor tachometer B9, a resolver B10, and an earth rate reference transformer T1.

The tangent latitude computer, which produces the east-west speed compensating signal, consists of a type 2 computer amplifier and resolver B11. A dial attached to the shaft of resolver B11, indicates the ship's latitude.

The input to the latitude computer is the north-south speed plus drift signal, and the inputs to the tangent latitude computer are the east-west speed signal, and the initial, manual, ship's latitude setting. The latitude is set by the compass operator at the start of a voyage and thereafter the latitude computer keeps the latitude up to date, automatically, wherever the ship may go.

The north-south speed plus drift signal is fed, in series opposing, with the output of the generator section of motor tachometer B9 (which produces a damping voltage for stabilization of the servo loop), to the input of the type 1 computer amplifier. The type 1 computer amplifier output drives the motor section of motor tachometer B9 at a speed corresponding to north-south speed plus drift. The motor shaft is geared down (240 million to 1) to position the rotor of resolver B10, so that it follows the changing ship's latitude. At any time, the position of the rotor of resolver B10 corresponds to the latitude position of the ship. With a reference voltage, representing earth rate, from transformer T1 impressed on the rotor of resolver B10, and the rotor set at the ship's latitude, resolver B10 functions to resolve its earth rate reference voltage and latitude inputs, into an output proportional to earth rate times the sine of the latitude, or vertical earth rate, and an output proportional to earth rate times the cosine of the latitude, or horizontal earth rate.

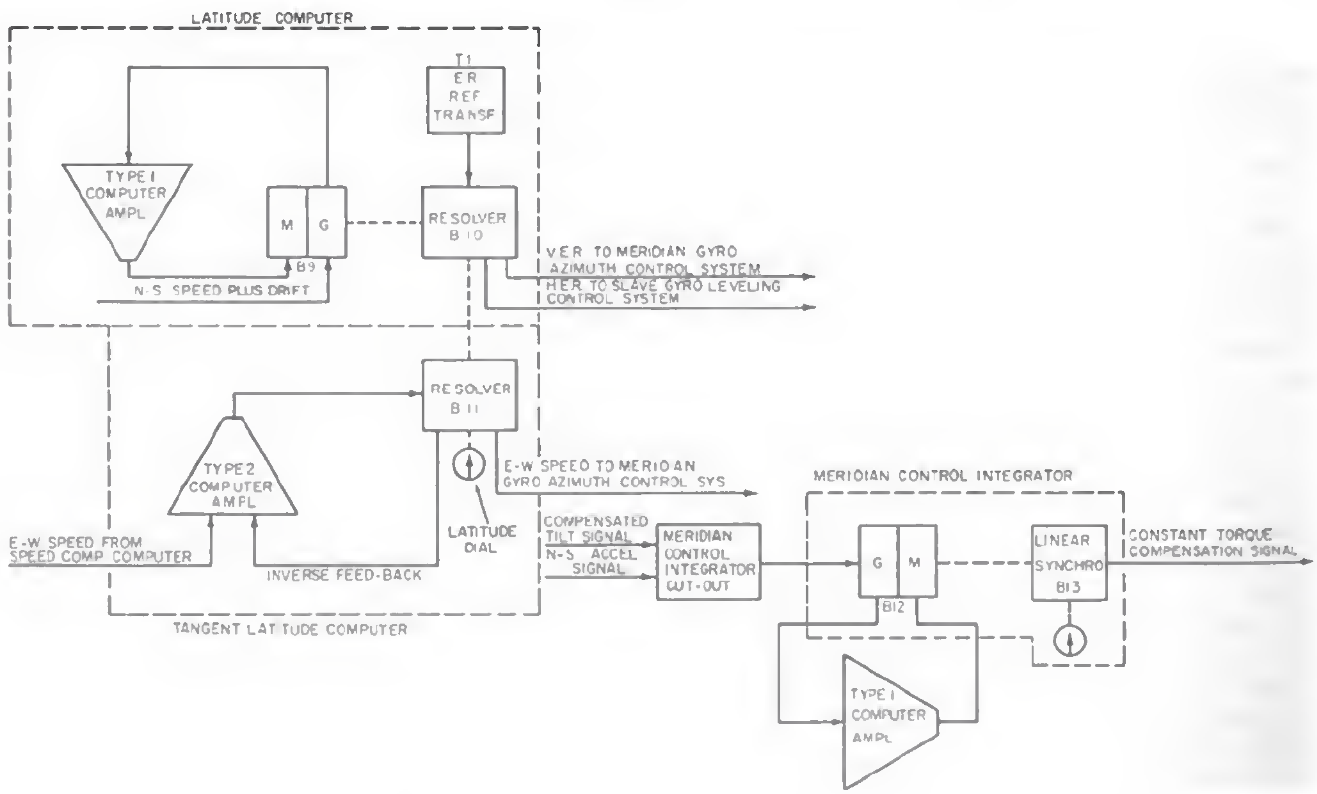

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Figure 6-12.—Earth rate and constant torque compensation signals.

The amplified east-west speed signal from the type 2 computer amplifier is fed to the rotor of resolver B11. With this voltage proportional to east-west speed on its rotor, and the rotor positioned to the ship's latitude, the outputs of the two resolver stator windings are proportional to east-west speed times the sine and cosine of the ship's latitude. The output of the cosine stator winding representing the cosine of east-west speed and latitude, however, is fed back, inversely, to the input of the type 2 computer amplifier so that the resultant output of the amplifier represents the product of east-west speed and the reciprocal of the cosine of the latitude. This output signal on the rotor of the resolver is multiplied by the sine of the ship's latitude in the sine stator winding with the resultant resolver output of this winding being proportional to the product of east-west speed and the tangent of the ship's latitude.

If the sensitive elements were perfectly balanced, and there were no other factors which would cause a constant torque on either of the two gyros, the tilt signals from the electrolytic bubble level, over a period of time, would average out to zero. This is true because the gyro controls are designed to keep the gyro axles level at all times. As it is not possible to keep the gyros perfectly balanced at all times because of wear, a constant torque compensation system is provided for both the meridian and slave gyros.

The meridian gyro constant torque compensation system (fig. 6-12) consists of a meridian control integrator which includes a motor-tachometer B12 and a linear synchro B13. The system also contains an integrator cutout and a type 1 computer amplifier. A dial is coupled to the shaft of linear synchro B13 to provide visual indication of integrator operation.

The meridian gyro compensated tilt signal is fed through a relay in the cutout in series with the damping voltage output of the generator section of motor-tachometer B12 to the input of the type 1 computer amplifier. The amplifier output drives the motor section of motor-tachometer B12, which is geared down, 3 million to one, to the linear synchro. Because of this high gear reduction it takes a great number of motor revolutions over a period of time to appreciably rotate the rotor of linear synchro B13. The linear synchro, therefore, for all practical purposes, does not respond to short time signals but responds to long time signals or the sum of fluctuating and short time signals. If the average signal from the electrolytic bubble level is not zero, and persists for a long period of time, such as mechanical unbalance of the compass would cause, the rotor of linear synchro B13 will turn gradually at a constant rate. The output voltage being of opposite phase to the tilt signal input, will tend to reduce the input slowly until the voltage output of the linear synchro exactly equals the tilt signal input caused by the unbalance.

The time constant, or rate of change, of the linear synchro output voltage for a given tilt signal is made slow enough so as not to affect the normal settling characteristics of the compass, and yet fast enough to compensate for any constant torque without appreciable delay.

If the magnitudes and durations of accelerations are excessive, during high speed turns and maneuvers for example, it is desirable to cut out the tilt signal to the integrator. This is done by feeding the north-south acceleration signal to the meridian control integrator cutout, which functions to operate a relay, cutting out the tilt signal during excessive accelerations.

For the tilt signal outputs from the electrolytic bubble level to average out to zero, all compensating signals must be computed exactly, in addition to the compass being perfectly balanced. The constant torque compensation system, then, will also compensate, within limits, for errors in the computation of other compensating signals.

The constant torque compensation system for the slave gyro is identical to the meridian gyro system.

AZIMUTH FOLLOWUP SYSTEM

The azimuth followup system (fig. 6-13) detects any misalignment between the vertical ring and gyrosphere and functions to drive the azimuth phantom (and therefore the vertical ring) back into alignment with the gyrosphere.

An azimuth pickoff, consisting of an E-shaped core transformer mounted on the vertical ring, and an armature cemented to the gyrosphere, furnishes the misalignment signal to the followup amplifier in the conventional manner. The followup motor, driven by the azimuth followup amplifier output, drives the azimuth phantom, restoring the azimuth pickoff to its neutral position and positioning, through gearing, the 1- and 36-speed heading

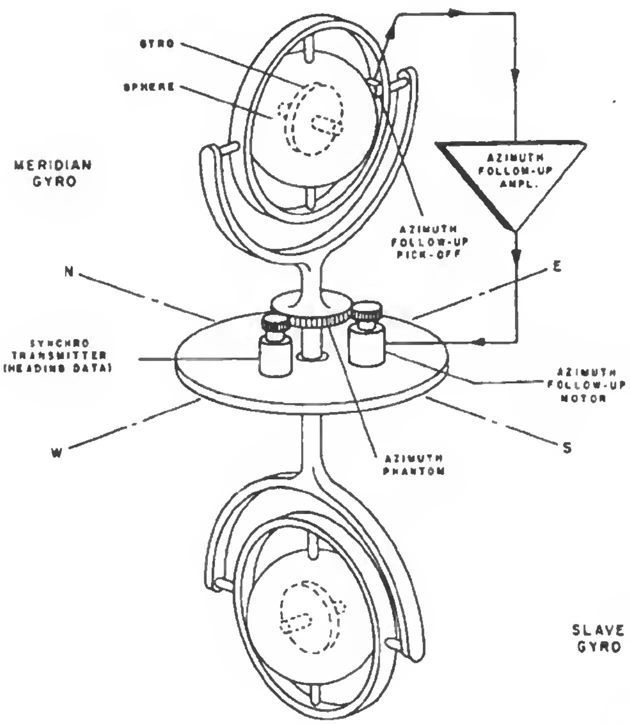

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Figure 6-13.—Simplified diagram of azimuth followup system.

data synchro transmitters. The followup motor also positions the rotor of the roll-pitch resolver (not shown in fig. 6-13) to a position corresponding to ship's heading.

The azimuth followup amplifier consists of a preamplifier stage, a demodulator stage with displacement and rate signal networks, and a magnetic amplifier output stage. Associated with the amplifier are two alarm circuits, which actuate the compass alarm in case of excessive pickoff signal or preamplifier tube failure.

ROLL AND PITCH FOLLOWUP SYSTEM

The roll and pitch followup system (fig. 6-14) detects and eliminates any misalignment between the roll-pitch phantom and the level position maintained by the two gyros. It also positions the roll and pitch synchro data transmitters. The system consists of two E-core pickoffs, two followup amplifiers, and two followup motors, all duplicates of the corresponding components in the azimuth followup system. In addition, the system includes a roll-pitch resolver.

The meridian gyro roll-pitch pickoff is mounted on the meridian gyro cradle and detects any misalignment between the cradle and the meridian gyro's vertical ring. This misalignment is about the meridian gyro's east-west horizontal axis. The roll-pitch phantom, being physically linked to the azimuth phantom, will be identically misaligned with the vertical rings of both gyros.

The slave gyro roll-pitch pickoff is mounted on the slave gyro cradle and detects any misalignment between the cradle and the slave gyro's vertical ring. This misalignment is about the slave gyro's north-south horizontal axis. Thus, any misalignment between the roll-pitch phantom and the vertical ring of either gyro, produces a roll-pitch pickoff signal.

A pitch followup motor is mounted on the gimbal ring, and meshed with the pitch gear on the roll-pitch phantom. It positions the roll-pitch phantom about the pitch axis. A roll followup motor is mounted on the support assembly and meshed with the roll gear on the gimbal ring. It positions the roll-pitch phantom about the roll axis, through the gimbal ring.

On the north-south course, the pickoff signal from the meridian gyro roll-pitch pickoff, if fed through the pitch followup amplifier to the pitch followup motor, would compensate for the effect of pitch. Similarly, if the pickoff signal from the slave gyro roll-pitch pickoff were fed through the roll followup amplifier to the roll followup motor, it would compensate for the effect of roll.

On an east-west course, however, the meridian gyro roll-pitch pickoff would have to be fed to the roll followup amplifier and motor, to compensate for roll, and the slave gyro roll-pitch pickoff would have to be fed to the pitch followup amplifier and motor, to compensate for pitch. It follows, therefore, that on any intermediate course, the roll-pitch motions of the ship will have components acting about both north-south and east-west axes, and both roll-pitch pickoffs will react to both roll and pitch. As a result, the two pickoff signals must be divided into proper proportions to each followup amplifier and motor to maintain the horizontal stability of the roll-pitch phantom. The own ship's course determines these proper proportions, and they are obtained from the roll-pitch resolver.

The roll-pitch resolver has its rotor positioned corresponding to own ship's course by the azimuth followup system as mentioned previously. The meridian gyro roll-pitch pickoff signal is fed to one resolver rotor winding, and

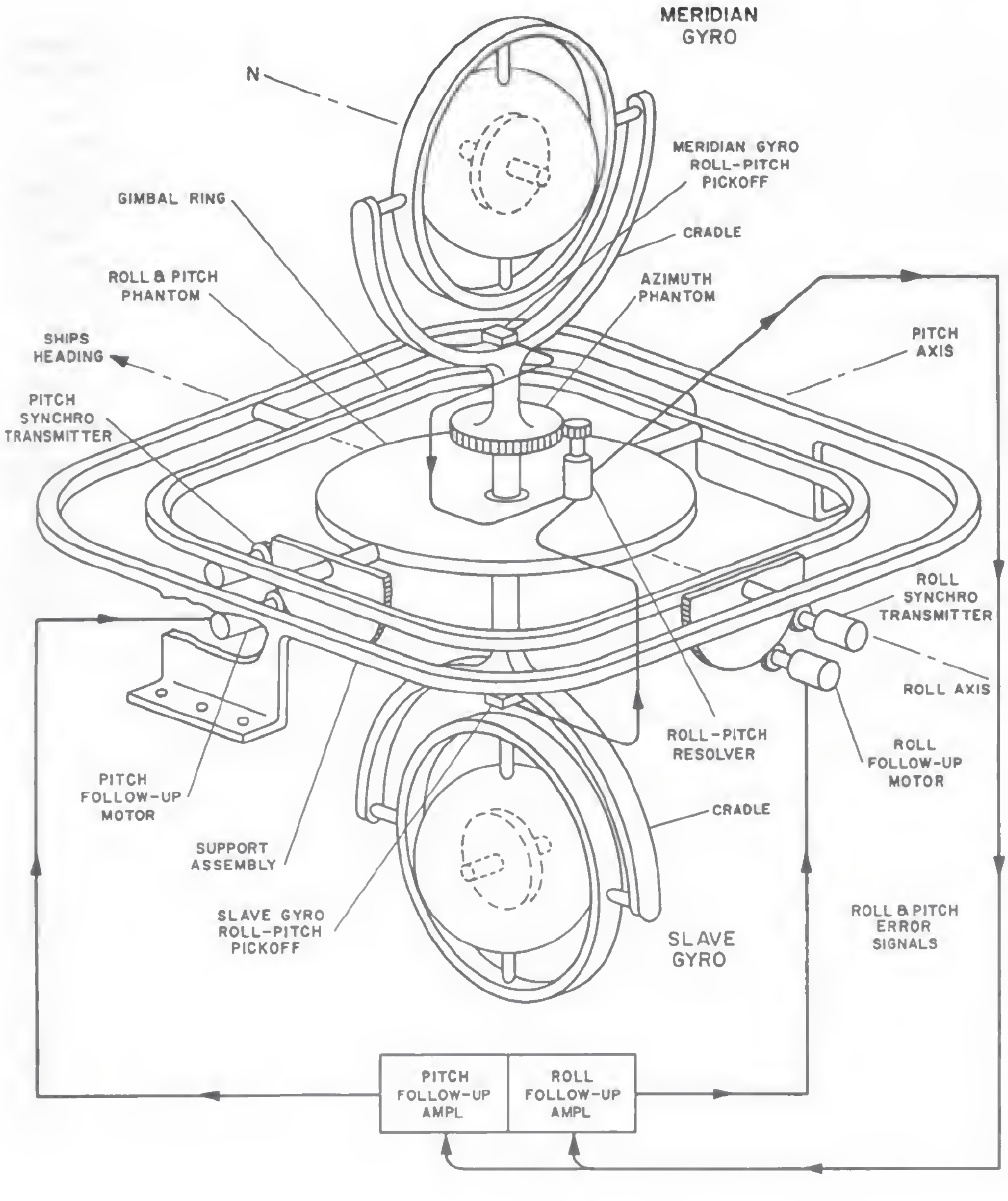

Figure 6-14.—Simplified diagram of roll and pitch followup system.

the slave gyro roll-pitch pickoff signal is fed to the other rotor winding. The resolver functions to resolve its own ship's course and roll-pitch pickoff input signals into output signals of proper proportions, to the followup amplifiers. The followup motors position the roll-pitch phantom until the pickoffs are restored to their neutral position, and at the same time, position 2- and 36-speed roll and pitch synchro data transmitters. Figure 6-15 shows a block diagram of the roll-pitch followup sequence.

Due to backlash, spring in gearing, and other effects, followup motors may have errors up to 0.05 degree. These errors are compensated for in the Mk 19 gyro compass by a data correction system (fig. 6-16). Three special type synchro transmitters are used in conjunction with three transistor data correction amplifiers, in transmitting the 36-speed heading, roll, and pitch data. The special type 36-speed synchro transmitter has an additional rotor winding displaced 90 electrical degrees from the normal rotor winding. When this additional, or quadrature, rotor winding is excited by a variable voltage, the magnetic field produced reacts with the magnectic field of the normal rotor winding, and thus produces a resultant rotor field which is displaced from the normal rotor winding field. The angle of this displacement is proportional to the magnitude and phase of the voltage applied to the additional rotor winding.

The three transistor data correction amplifiers are sealed and mounted in the bottom of the master compass. The input signals to the amplifiers are a portion of the azimuth followup signal, roll followup signal, and pitch followup signal. The signal is amplified and demodulated using the pickoff excitation voltage as a reference. The demodulator output (a d-c voltage proportional to the pickoff signal) is modulated using the synchro excitation voltage as a reference, as shown in figure 6-16. The output of the amplifier to the quadrature synchro rotor winding is a voltage proportional to the followup error, thus the transmitted data is corrected by an amount equal to the followup error. The transmitted data then indicates the true attitude of the gyros, rather than the phantom ring assembly.

ALARM SYSTEM

An alarm system is incorporated in the Mk 19 Mod 3 gyrocompass system to the extent that

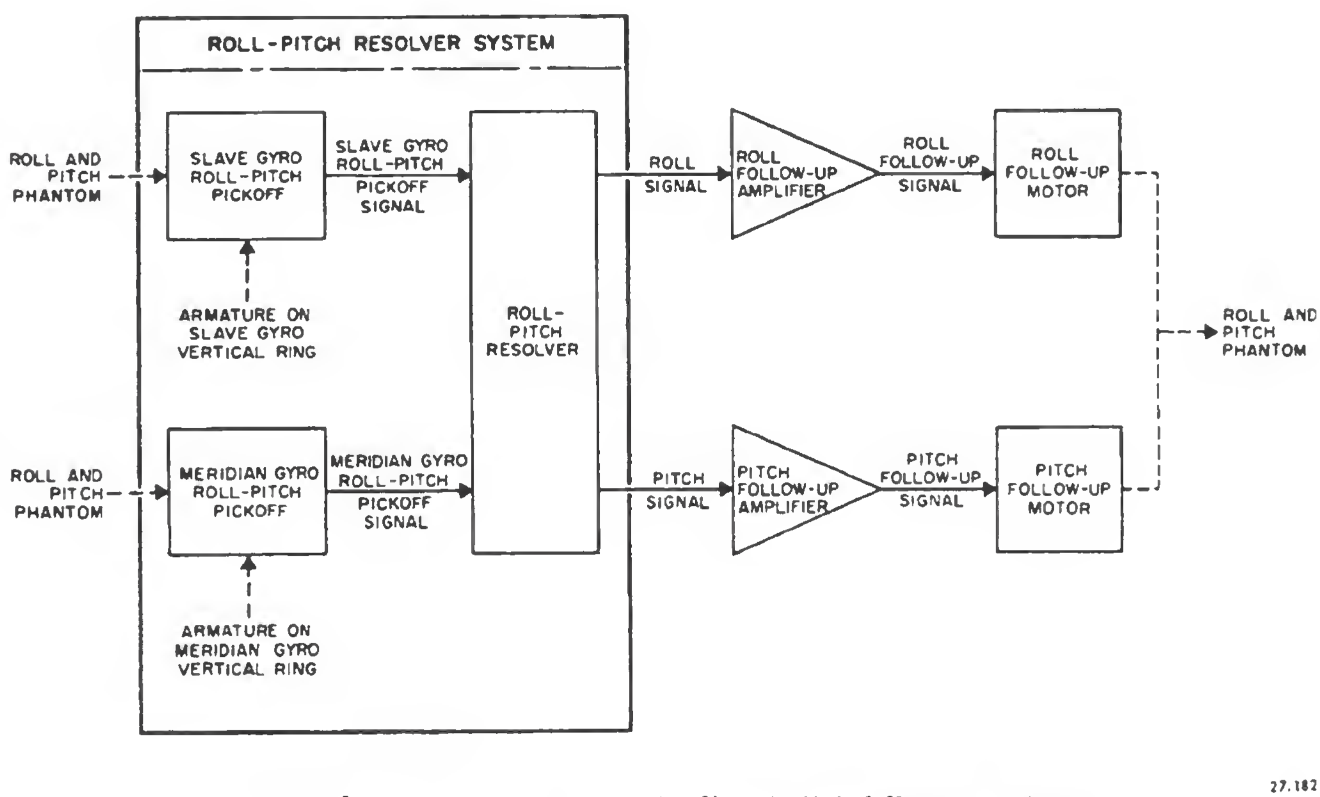

Figure 6-15.—Block diagram of roll and pitch followup systems.

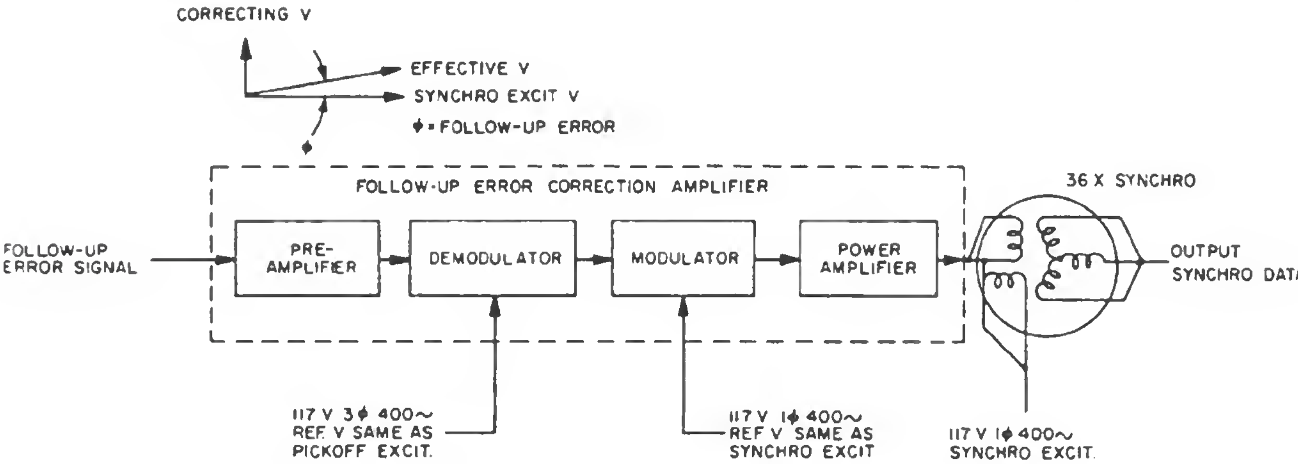

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Figure 6-16.—Block diagram of data correction system.

each loop in the system will give multiple alarm warnings when a trouble develops in that loop. In addition, as trouble may also develop in the alarm circuits, the circuits are so arranged as to give alarm warnings when they themselves become defective. This is accomplished in each alarm circuit by using normal tube current to energize an alarm relay. Therefore, if trouble develops within that circuit to reduce tube current, the relay will deenergize and actuate the alarm.

Figure 6-17 shows in block form the points at which each loop in the system is alarmed. This figure does not show every alarm that will give warning, but merely the place in the loop where the initial alarm will occur. The complete alarm system may be divided into three separate systems, the followup alarm system, the compass control alarm system, and the ship's 400-cycle supply alarm system.

The followup alarm system consists of two alarm circuits in each followup amplifier. As the three followup amplifiers are identical, the alarms in each are identical. The alarm circuits are the preamplifier tube failure alarm and the followup error alarm. Two neon indicating lamps on each amplifier are provided to give a visual indication of the source of trouble when an alarm is actuated.

The compass control alarm system consists of nine computer loops and four torquer loops. These thirteen computer and torquer loops have associated with them eleven type 1 and two type 2 computer amplifiers, with alarm circuits. Also each of the compass control signals pass through the computer control assembly. An alarm circuit is employed that will actuate the compass alarm when any tube in the assembly becomes defective. A failure in any loop circuit will actuate the alarm and cause a neon indicating lamp to light on the associated computer amplifier, or amplifiers, and any tube failure in the computer control assembly will cause a similar indicating lamp to light on the computer control assembly panel.

The ship's 400-cycle supply alarm (not shown in fig. 6-17) is actuated in the event of failure of any phase of the ship's 3-phase 400-cycle supply, or a drop in supply voltage below 102 volts. Undervoltage detection circuits and associated relays in the system control assembly (fig. 6-6), actuate the alarm, disconnect the compass from the ship's supply line, and operate the standby supply as a generator. A green, ship's supply indicating light on the control panel is extinguished and a red standby supply light lights, showing that the ship's 400-cycle supply has failed and the compass is operating on the standby supply.

Figure 6-18 shows a block diagram of the action of the complete alarm system. The flashing lamps in the compass failure annunciator are actuated by flasher units in the system control assembly (fig. 6-6).

AUXILIARY CONTROL SYSTEMS

To aid in starting and operating the master compass, two auxiliary control systems are

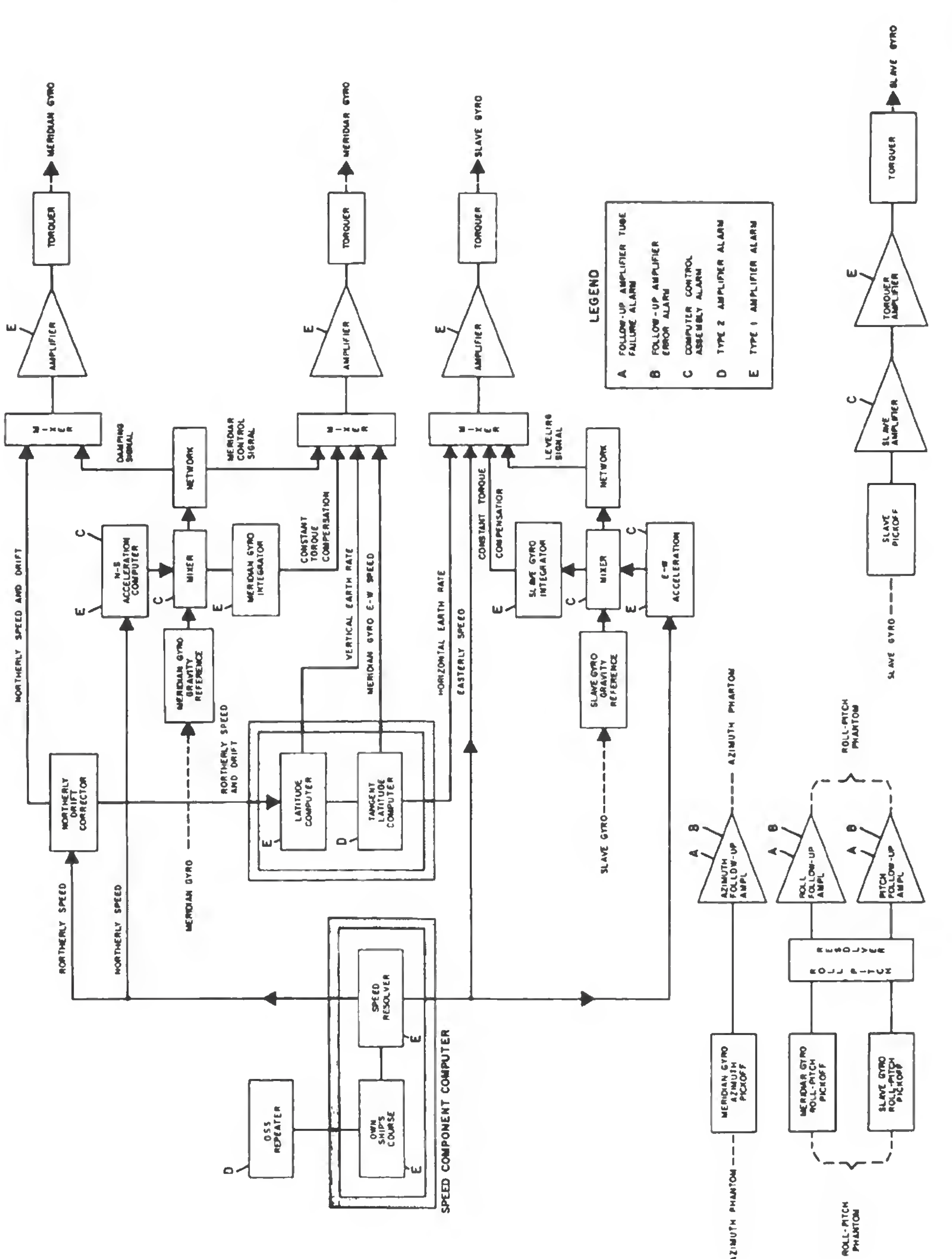

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Figure 6-17.—Alarm points in compass control and followup circuits.

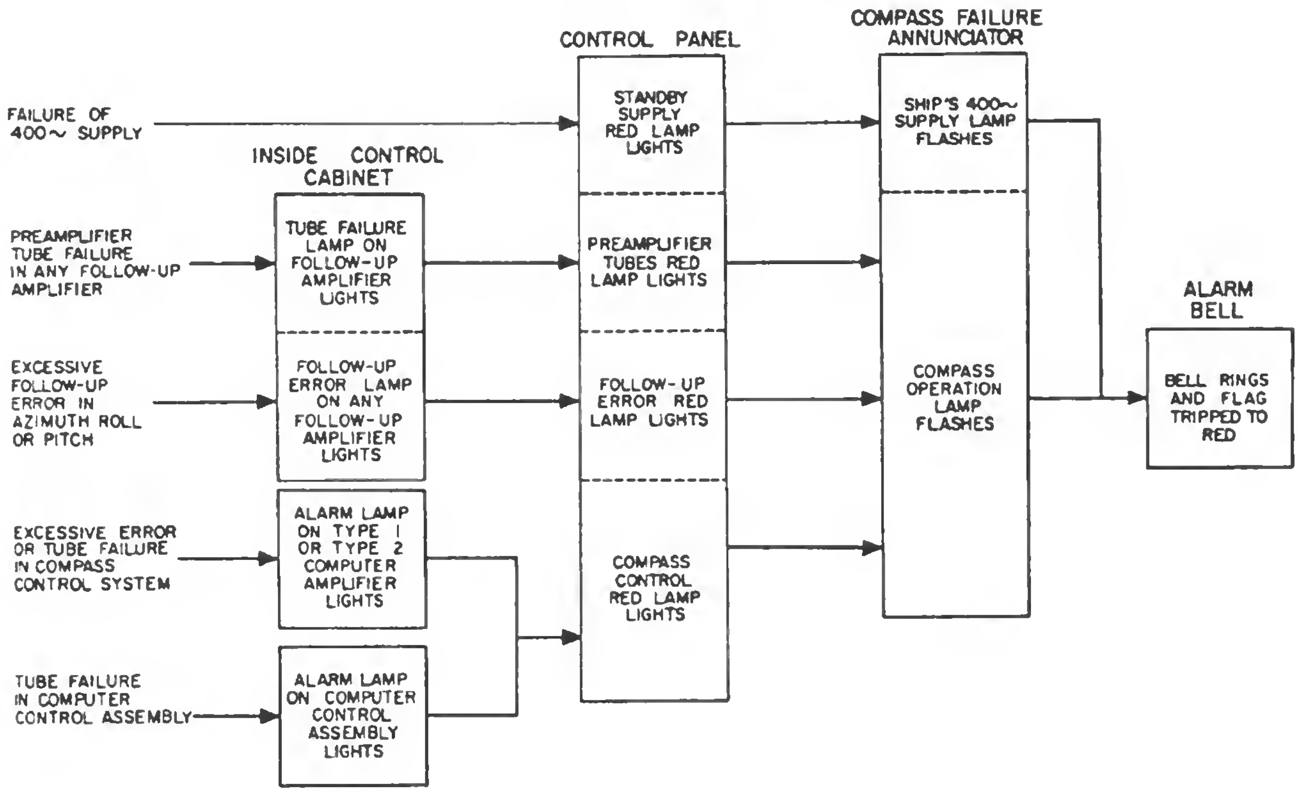

Figure 6-18.—Block diagram of complete alarm.

provided; the starting system, and the fast settling system.

The starting system is provided to level the gyros and bring the meridian gyro to the meridian in as short a time as possible, when starting, with a minimum number of manual operations by the compass operator. The system includes a fast erect system, the system control assembly, and part of the control panel.

When the compass is to be started the roll-pitch phantom will be off its level position. A fast erect system is employed, which greatly reduces the time required to bring the roll-pitch phantom (and therefore the gyros as they are caged to their vertical rings and the azimuth phantom during starting) to a level position. This sytem utilizes a small stabilizer or start gyro mounted in the gimbal, which when started, comes very quickly to a vertical position, providing a fairly accurate level reference for the roll-pitch phantom.

The stabilizer gyro rotor is the squirrel cage portion of a 3-phase, 115-volt, 400-cycle induction motor, and spins within the stator at 22,500 rpm in ball bearings which are in the top and bottom of the gyro case. A ball erector mechanism (fig. 6-19) is employed for maintaining the gyro spin axis vertical. This mechanism consists of a flat cylindrical enclosure suspended from the gyro case by means of a ring which also serves as a bearing surface. It is geared to the rotor shaft and rotates at 22 rpm about an axis parallel to the gyro spin axis. When the gyro is vertical, eight small balls are massed in the center of the concave surface of a disk in the bottom cover. Eighteen holder pins are equally spaced near the edge of the concave disk. When the gyro tilts, the balls roll to the lower side of the disk, where they are held loosely by the holder pins and carried ahead, in the direction of rotation, toward the higher side. As each ball reaches a point where it can drop past the holder pin, it falls across the disk and resumes its cycle. The center of gravity of the balls, so displaced, is at a point 90 degrees from the low point, in the direction of rotation. Thus, a torque is created which precesses the gyro back to a vertical position, causing the balls to cluster

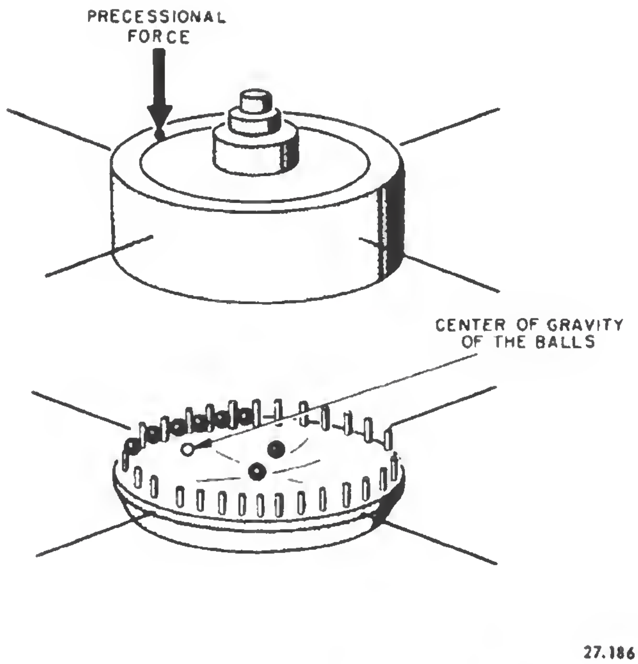

Figure 6-19.—Ball erector diagram.

in the center of the disk, exerting no precessional force. Rotation of the gyro is clockwise viewed from above. The ball holder rotates in the same direction, and is easily observed because of its slow speed.

Flat roll and pitch synchro transmitters are mounted on the stabilizer gyro (fig. 6-20). The output from the pitch transmitter B13 is fed to a control transformer B14 mounted on the master compass and meshed with the pitch gear. The output signal from control transformer B14 represents the amount of pitch error in the roll-pitch phantom. This error signal is fed through the pitch followup or servoamplifier, to the pitch followup motor, which positions the roll-pitch phantom until pitch error has been removed.

The output from the roll transmitter B15 is fed to control transformer B16, mounted on the compass frame and meshed with the roll gear. The roll followup motor positions the gimbal ring until roll error has been removed.

The roll-pitch signals from control transformers B14 and B16 are fed through the first three positions of a stepping relay, to the followup amplifiers. The steppping relay automatically disconnects these roll-pitch signals and connects the roll-pitch output signals from the roll-pitch resolver to the proper followup amplifier, when the main gyros have attained sufficient gyroscopic rigidity to take over the stabilization of the roll-pitch phantom.

The stepping relay is an 11-deck 12-position magnet-operated unit located in the system control assembly (fig. 6-6). This relay, in conjunction with other time delay relays, serves to connect the various components automatically at the proper time during the starting sequence. Many operations are involved in starting the compass and the steps must be performed in the proper sequence and at the proper time in order to bring the compass to a usable condition in an optimum amount of time.

STARTING SYSTEM

The Mk 19 starting system is made as nearly automatic as possible. The only manual operations required of the compass operator are the master switch, manual azimuth switch, fast settle switch, and the run button, located on the compass control panel (fig. 6-4). The manual azimuth switch operates controls for slewing the compass in azimuth that are very similar to those described in the Mk 23 system.

FAST-SETTLING SYSTEM

The fast-settling system is employed to reduce the compass period, and increase the percent of damping, during starting, which reduces the time required for the gyros to assume a true level position and the meridian gyro to settle on the true meridian.

This system is actuated by the fast-settle switch located on the control panel (fig. 6-4) and a fast-settle relay located in the computer control assembly.

One section of the switch is used to energize the 4-pole double-throw fast-settle relay. The fast-settle relay operates to alter resistor connections in the meridian gyro gravity reference system which increases the damping signal output, and also obtains the voltage for the primary of the meridian control step-up transformer directly from the cathode follower instead of from a potentiometer, thereby increasing the meridian control signal output. In addition the relay operates contacts shorting a potentiometer in the slave gyro gravity reference system, which increases the slave gyro leveling signal.

Another section of the fast-settle switch disconnects the alarm circuit from the alarm delay relay rendering the compass failure

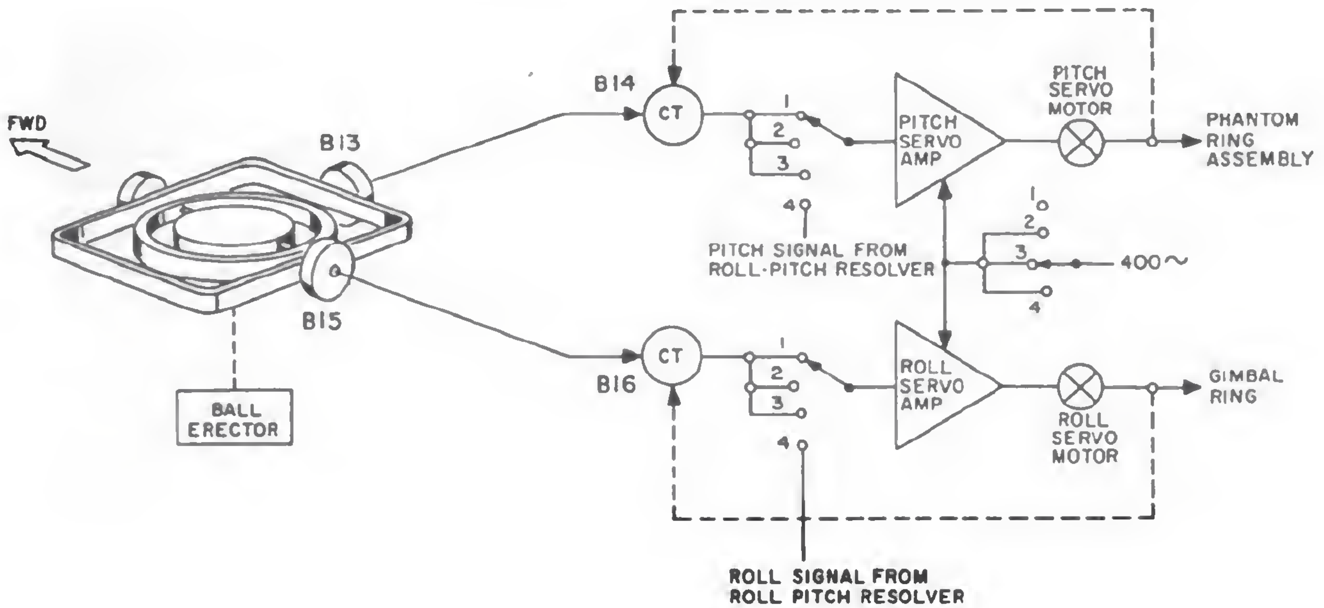

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Figure 6-20.—Fast erect system.

alarms inoperative during fast-settle operation. A third section of the switch connects the fast-settle lamp (fig. 6-4) across a transformer output to give visual indication of fast-settle operation.

MAINTENANCE AND TROUBLESHOOTING

The design and construction of the Mk 19 Mod 3 gyrocompass are such that once it has been properly calibrated and adjusted it should provide reliable operation over long periods of time. Routine preventive maintenance procedures required by the compass operator to ensure uninterrupted operation must be performed carefully and regularly. These procedures include frequent visual inspections of all indicating lamps and dials provided for observing system operation, periodic tests of the various components of the system, and routine cleaning and lubricating.

The manufacturer's technical manual contains detailed information concerning testing the various circuits, systems, and components, and analyzing and evaluating the results of these tests. Study the technical manual and acquaint yourself thoroughly with the normal operating conditions of the system. This will enable you to recognize any abnormal condition immediately by visual inspection.

CLEANING AND LUBRICATING

All electrical contacts should be kept clean and smooth. Contacts of the various plugs, receptacles, and rotary switches are silver plated and the sliprings are gold plated. All of these contacts should be cleaned only with a cloth and an approved solvent. All relay contacts may be cleaned with crocus cloth.

The master compass should be cleaned after securing. Clean all exposed gears and sliprings with a cloth and solvent. Polish all sliprings with a dry cloth to remove any film left by the solvent. Wipe the inside of the compass binnacle, using a cloth and solvent.

The standby power supply should be cleaned monthly. Remove and clean end bell covers using a stiff brush. Clean the commutator and sliprings with a cloth and solvent. Clean between commutator bars with a small nonmetallic brush then wipe the commutator and sliprings clean with a dry cloth. Inspect the brushes and make sure no dirt is between them and the commutator. The bearings are grease sealed and require no lubrication.

The control cabinet should be cleaned as necessary. Wipe off the dust with a clean cloth, or use a vacuum cleaner. All units within the

control cabinet requiring lubrication have grease-sealed bearings.

All exposed gears, the azimuth servo assembly, roll servo assembly, pitch servo assembly, and phantom ring should be lubricated according to the manufacturer's technical manual or lubrication charts for the Mk 19 compass. Care should be taken to avoid overlubrication as excessive oil will form a mist within the compass binnacle and cause trouble with the electrical components.

The meridian and slave gyro assemblies are sealed units and require no lubrication.

LOCALIZING FAULTS

Most faults or casualties occurring to the Mk 19 Mod 3 gyrocompass will be indicated by the compass failure annunciator and alarm bell. The annunciator indicates whether the failure is in the ships supply or in the compass operation. Indicator lamps on the control panel will indicate which control loop is affected by the failure. In addition, indicator lamps on the various assemblies inside the control cabinet will indicate which assembly is the probable cause of the failure (fig. 6-18). Thus the alarm system localizes the source of trouble.

In many cases the fault will be corrected by replacing an electron tube in an amplifier or replacing the amplifier with a spare unit as indicated by the alarm system. All type 1 and type 2 computer amplifiers, the three followup amplifiers, and the d-c power supply unit are designed for easy replacement. If trouble is indicated in the slaving torquer amplifier it should be replaced immediately as the compass will tumble in 15 minutes without this amplifier.

If excessive followup error is indicated in one of the followup systems and replacement of the followup amplifier concerned does not correct the fault, the trouble may be in the servo gear train. This may be improper gear mesh, excessive backlash, or a dirty gear train. Excessive backlash produces the same effect as too large an amplifier gain (jitters). A dirty, sticky, or improperly meshed gear train will overload the followup system and prevent alignment. The tightness of the servoloop may be checked by rotating the servomotor damper and observing how well the servo returns to zero when released. Means for adjusting backlash are provided for all followup gear trains. Dirty gears should be cleaned with a solvent, and relubricated. The manufacturer's technical manual contains a troubleshooting chart for each synchro and servoloop and for the various components in the system. As it is important to locate and correct a fault as quickly as possible you should resort to the use of test equipment and troubleshooting charts only after you have been unable to determine the trouble by visual inspections or routine tests for proper operation.

CHAPTER 7

DEAD RECKONING SYSTEM

The dead reckoning system, circuit TL, provides a means of indicating the ship's position in latitude and longitude on an appropriate chart by means of a range-bearing projector (plotting light), or on mechanical dials. It may also record graphically on an appropriate chart, the ship's travel relative to a fixed starting point. When properly set at the starting point, the mechanisms of the dead reckoning equipment indicate continuously the ship's latitude and longitude by computing mechanically the distance traveled by the ship and the ship's course. The distance traveled is computed from the input received from the underwater log; the course input is received from the master compass.

DEAD RECKONING EQUIPMENT

Dead reckoning equipment (DRE) comprises a (1) dead reckoning analyzer and (2) dead reckoning tracer. A dead reckoning indicator is included with the tracking mechanism in the dead reckoning tracer. A block diagram of the dead reckoning system is illustrated in figure 7-1.

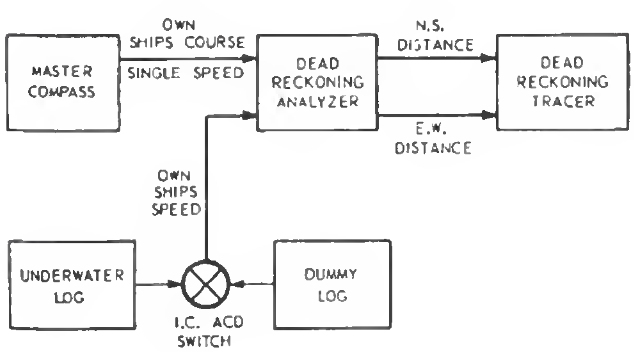

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Figure 7-1.—Dead reckoning system block diagram.

DEAD RECKONING ANALYZER

The dead reckoning analyzer (DRA) receives the ship's distance input from the underwater log system, and the ship's course input from the master-compass 1-speed transmitter. These two inputs are combined to determine and indicate the total distance and also the overall distances in a north-south and an east-west direction traveled by the ship from any given starting point. This analyzer unit consists of (1) a distance converter; (2) roller carriages; and (3) a ship's course crank arm mechanism enclosed in a metal case provided with a hinged cover (fig. 7-2). The east miles counter, north miles counter, total miles counter, and course dial are visible through a window in this cover. The dead reckoning analyzer is designed for bulkhead mounting and is located in the chart house.

Distance Converter

The distance converter is illustrated in the schematic diagram of the DRA in figure 7-3. It includes a distance input differential synchro receiver, G, which is electrically driven by the underwater log distance transmitter. The differential receiver acts as an ordinary receiver and turns at the rate of 360 revolutions per mile.

The distance input synchro, G, is geared directly to the shaft on which the two disks, M1 and M2, are mounted; therefore, their rotation is directly proportional to the distance traveled. It is from the rotation of these disks that the north and east components of the ship's travel are taken. Thus, they are called the north and east component disks. The counter, J, which is geared to the shaft that drives the disks, indicates the total miles traveled by the ship.

Roller Carriages

The roller carriages, P1 and P2 (fig. 7-3), are mounted on guide rods R1 and R2. The

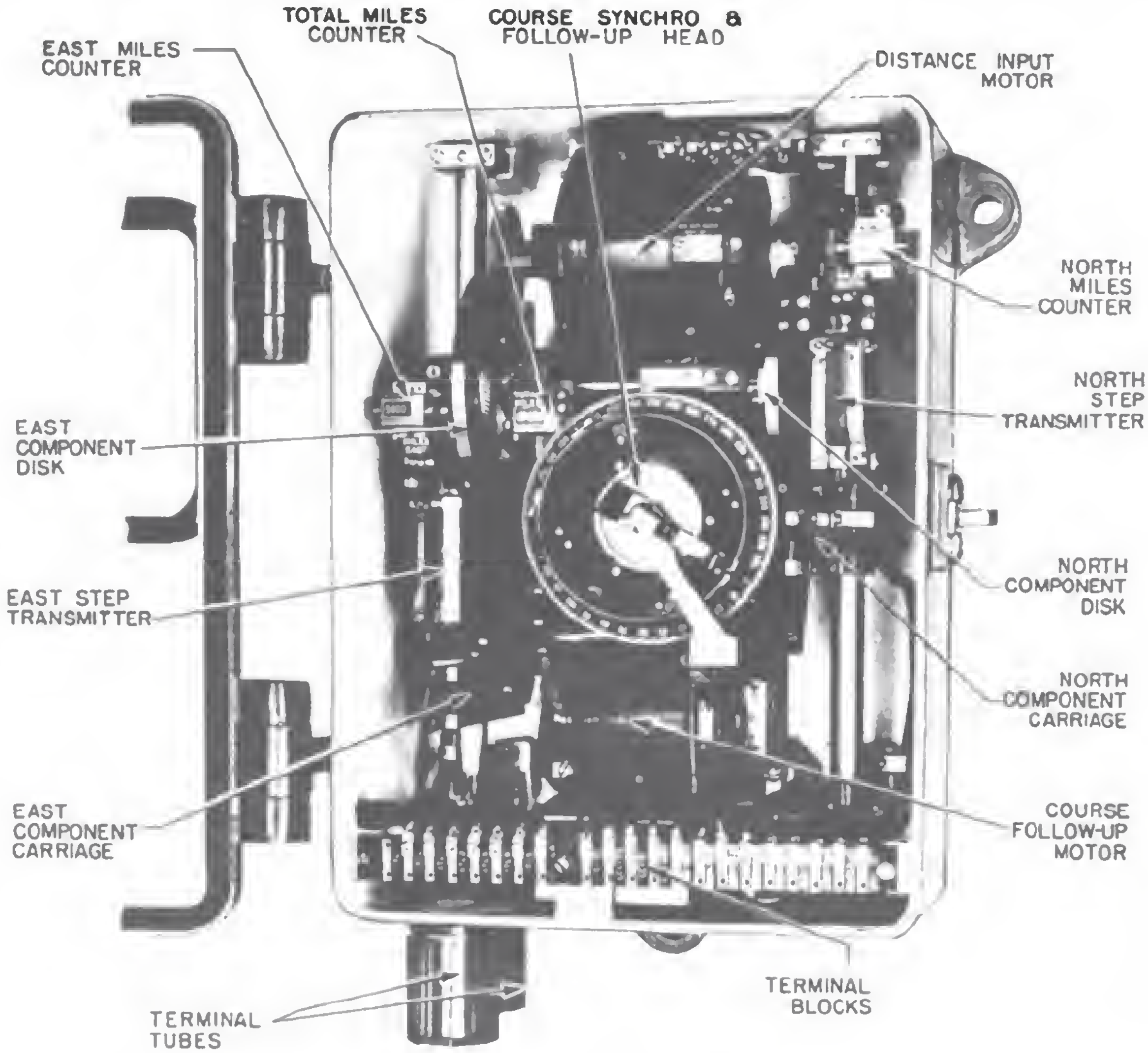

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Figure 7-2.—Dead reckoning analyzer.

ends of the roller carriages are provided with a set of guide rollers (not shown) to ensure free motion of the carriages along the guide rods. The carriages are positioned along the guide rods by a crank arm mechanism that is controlled by the signal from the master compass. The distance rollers, L1 and L2, are mounted on the north and east roller carriages respectively, and bear against the corresponding disks, M1 and M2. These rollers are positioned so that their turns are proportional to the north-south and east-west components respectively of the ship's distance.

When a carriage is positioned so that its distance roller is near the edge of its component disk, the roller is driven a maximum number of revolutions by each revolution of the disk. As the distance roller is moved toward the center of the disk, it is driven at a slower rate. When the roller is at the center of the disk, it is stationary, and no motion is transmitted to its shaft. Conversely, if the distance roller passes the center of the disk, it will be driven in the opposite direction.

The crank arm mechanism positions the carriages so that on a north-south or an east-west course, one of the distance rollers is at the edge of, and the other distance roller is at the center of, its component disk. Thus, on a north or south course, the north distance roller

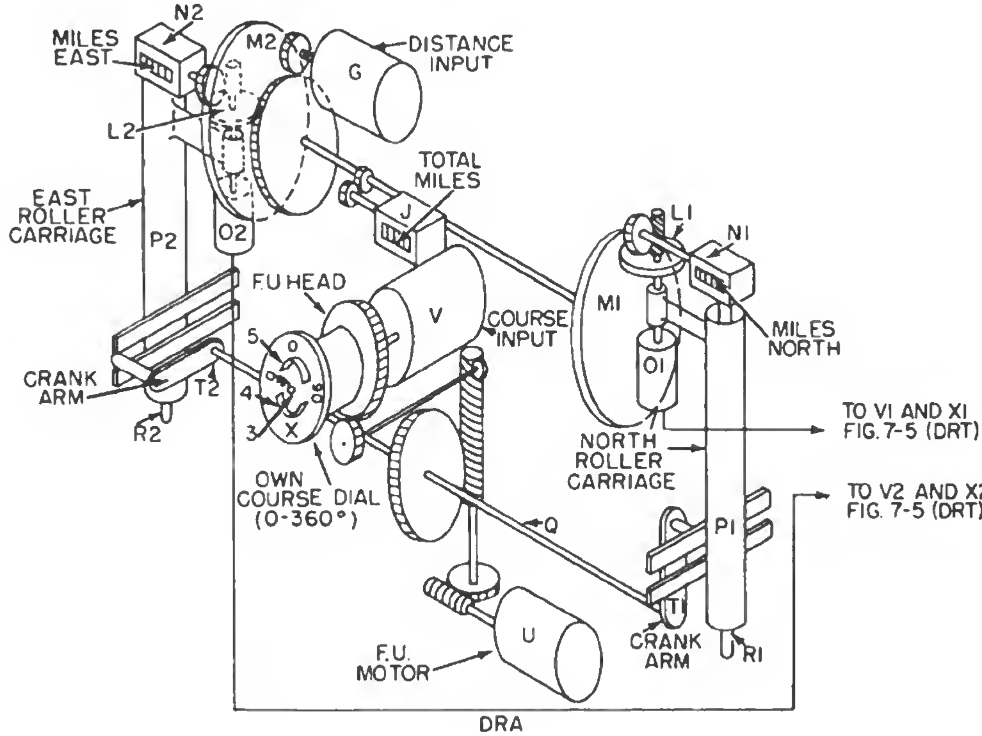

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Figure 7-3.—DRA schematic diagram.

is driven at a maximum rate, and the east distance roller is stationary. Conversely, on an east or west course, the east distance roller is driven at a maximum rate, and the north distance roller is stationary. On an intermediate course, both distance rollers are driven, the respective rates of rotation being proportional to the north-south and the east-west components of the ship's course.

The distance rollers, L1 and L2, drive the north counter, N1, and the east counter, N2, through worm gears to indicate the ship's travel in total miles north and in total miles east. Motions to the north or to the east are assumed as positive and cause the counters to indicate increasing readings. Conversely, motions to the south or to the west are assumed as negative and cause the counters to indicate decreasing readings.

The d-c step-by-step transmitters, O1 and O2, are mounted on the shafts of the distance rollers, L1 and L2, respectively. These transmitters control the step-by-step receivers, V1 and V2, respectively, in the dead-reckoning indicator and also the receivers, X1 and X2, in the dead-reckoning tracer. The rotation of these receivers is therefore directly proportional to the north or east components of the ship's travel and can be used to operate the desired indicating and recording mechanisms in the dead-reckoning tracer.

Ship's Course Crank Arm Mechanism

The ship's course crank arm mechanism (fig. 7-3) includes a course input synchro receiver, V, that is electrically driven by the master-compass transmitter. This receiver cannot furnish sufficient power to operate the crank arm mechanism; hence, a followup system is required. The synchro receiver controls the followup motor, U. The motor, through a gear train, moves a compass dial, X, and the crank arms, T1 and T2, that control the positions of the north and east roller carriages, P1 and P2, respectively.

The crank arms are mounted at right angles to each other on a common shaft (fig. 7-3). The crank pins engage slots in the roller carriages. These slots are at right angles to the guide rods, R1 and R2. When either crank arm is at right angles to its associated guide rod,

the throw of the crank arms positions its speed roller at the center of the associated disk, and no motion is transmitted to it. Conversely, when either crank arm is parallel to its guide rod, the throw of the crank arms positions its speed roller at the edge of the associated disk, and maximum motion is transmitted to it.

The ship's course dial, X, the split ring segments, 4 and 5, and the crank shaft, Q, are geared to the followup motor, U, and rotate with it when the motor is energized. The rotor of the course synchro receiver will not change its position with respect to its stator except when the course indication from the master compass changes.

Contact brush 3 is mounted on the shaft of the course synchro receiver, which extends through the ship's course dial mounting and can rotate freely within it. This brush can come into contact with either of the two segments of the split ring, which are connected to the followup motor. This action will cause the followup motor to run either in a clockwise or in a counterclockwise direction, depending on which segment is contacted by the brush. Normally, the brush is in the dead space between the rings and does not touch either ring, and the followup motor does not operate.

When the rotor moves in response to a change in course, contact is made on one of the split-ring segments. The followup motor then moves the crank arms, the ship's course dial, and the split ring assembly in a direction that brings the split ring into synchronism with the brush. In this position the course dial indicates the true heading, and the roller carriages are correctly positioned by the crank arms to provide the proper north and east components as the output of the analyzer. When there is no longer a change in compass course, the synchro receiver rotor stops turning but the segments continue to turn until the brush is in the dead space between the segments, and the followup motor stops.

DEAD RECKONING INDICATOR

The dead reckoning indicator (DRI) is contained in the tracking mechanism of the dead reckoning tracer. It consists of a dial unit assembly that includes the latitude motor and dials, longitude motor and dials, and latitude correction mechanism (fig. 7-4). The latitude and longitude dial assemblies each consist of two concentric dials. The outer latitude and longitude dials are graduated in degrees and the inner latitude and longitude dials are graduated in minutes.

A schematic diagram of the DRI is illustrated in the schematic for the DRT in figure 7-5. The output from the north step transmitter, 01, in the DRA drives the latitude step receiver, V1, that is geared to the latitude dials. Similarly, the output of the east step transmitter, 02, drives the longitude step receiver, V2, that is geared indirectly to the longitude dials through a speed correction mechanism.

The latitude dials, F1, are geared directly to the latitude step receiver. There is a fixed relation between a degree of latitude and a degree of displacement of the receiver rotor. (One degree of latitude is approximately equal to 60 nautical miles anywhere on the earth's surface.) A reversing latitude and longitude indicator switch, T, is provided for reversing the direction of rotation of the latitude dials when the equator is crossed.

LATITUDE CORRECTION MECHANISM

The longitude dials cannot be geared directly to the longitude step receiver because the relation between a degree of longitude and a degree of displacement of the longitude step receiver, V2, varies with the latitude. The latitude correction mechanism (fig. 7-5) is introduced between the longitude receiver, V2, and the longitude dials, F2, in order to adjust the number of miles east-west per degree of longitude in accordance with the latitude of the ship. This mechanism consists of a friction disk and roller assembly. The disk is attached to the shaft of the longitude motor, V2, and drives the friction roller at a speed proportional to the radial distance to the center of the disk. A cam follower is driven by a cam geared to the latitude degree dial and controls the position of the friction roller to provide the proper speed ratio for the given latitude. Thus, at 60° latitude, where 1° of longitude equals approximately 30 miles, the cam holds the friction roller in a position so that it turns twice as fast as it would turn at the equator. A spur gear meshes with a gear on the friction roller that drives the longitude dials, F2. The reversing switch, T, also provides for changing the direction of rotation of the longitude dials when the 0° or 180° meridian of longitude is crossed.

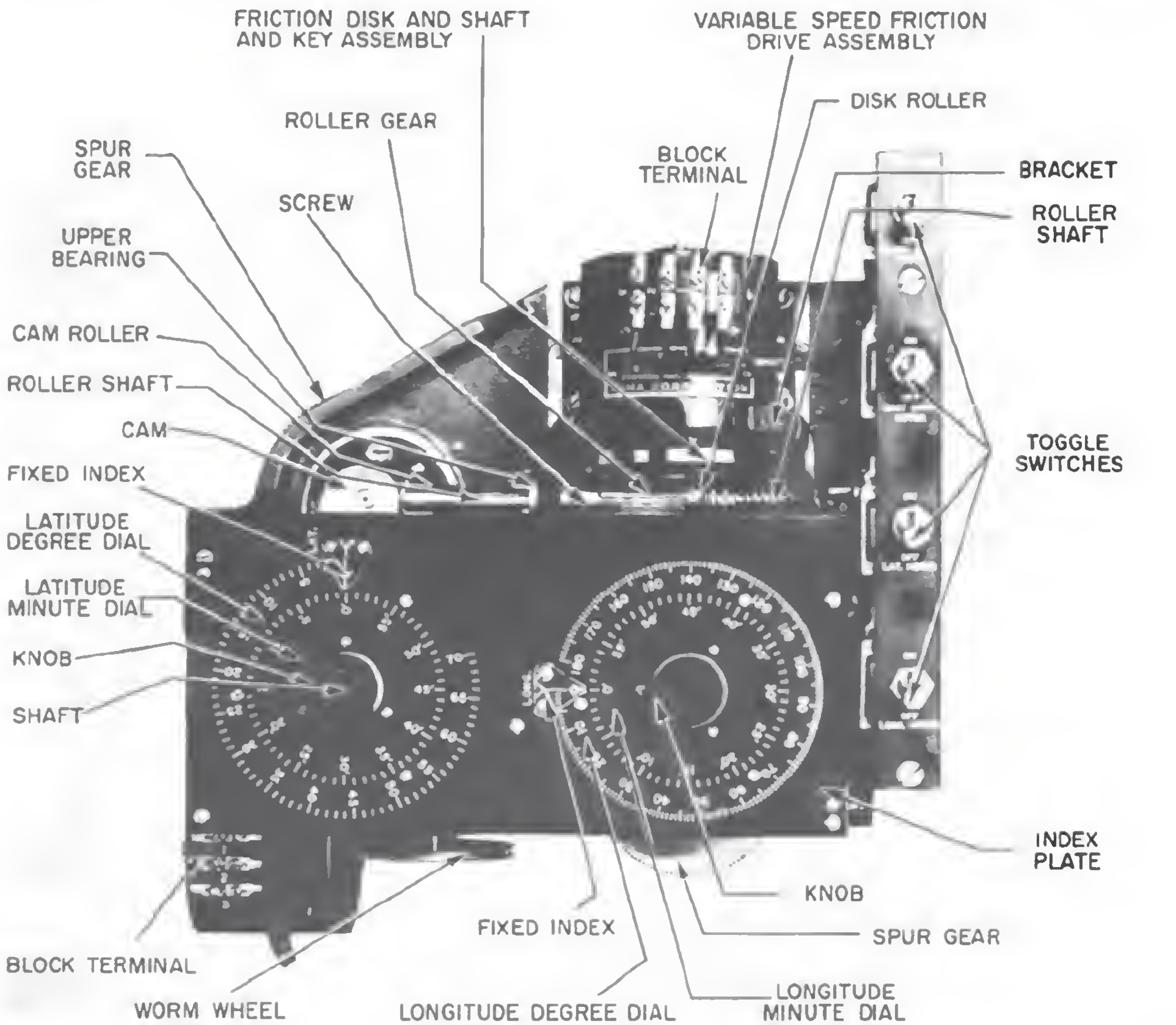

Figure 7-4.—Dead reckoning indicator.

DEAD RECKONING TRACER

The dead reckoning tracer (DRT) consists of (1) a tracking mechanism; (2) a chart board that includes the pencil carrier assembly; and (3) an auxiliary plotting board (fig. 7-6). The auxiliary plotting board is included with the DRT for plotting ranges and bearings of contacts that are being tracked, and for plotting own ship's course. The DRT is housed in a metal case designed for horizontal mounting on a table or cabinet and is located in the combat information center.

A schematic diagram of the DRT is illustrated in figure 7-5. The DRT, in addition to the DRI, receives from the DRA the outputs of the north and the east step transmitters, 01 and 02, that actuate the step receivers, X1 and X2, respectively. These step receivers in turn operate the mechanisms that drive the pencil carrier to record a graphical plot of the distance and direction traveled by the ship. The receivers, X1 and X2, are turned at the same rate as the speed rollers, L1 and L2, are turned by the component disks, M1 and M2.

TRACKING MECHANISM

The tracking mechanism is located in the right-hand section of the DRT case (fig. 7-6). It consists of a cross screw drive unit assembly and a lead screw drive unit assembly. The

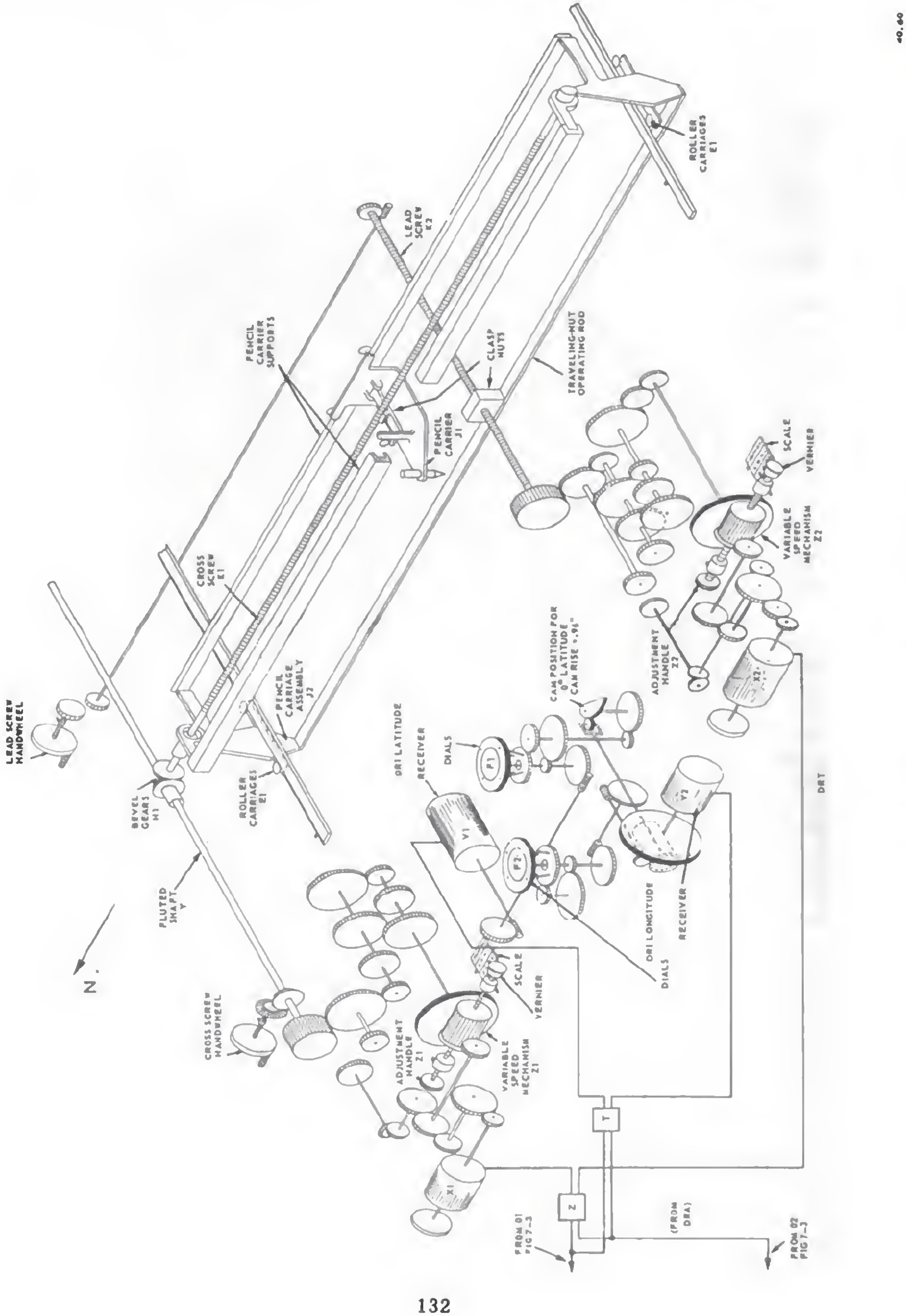

Figure 7-5.—DRT schematic diagram.

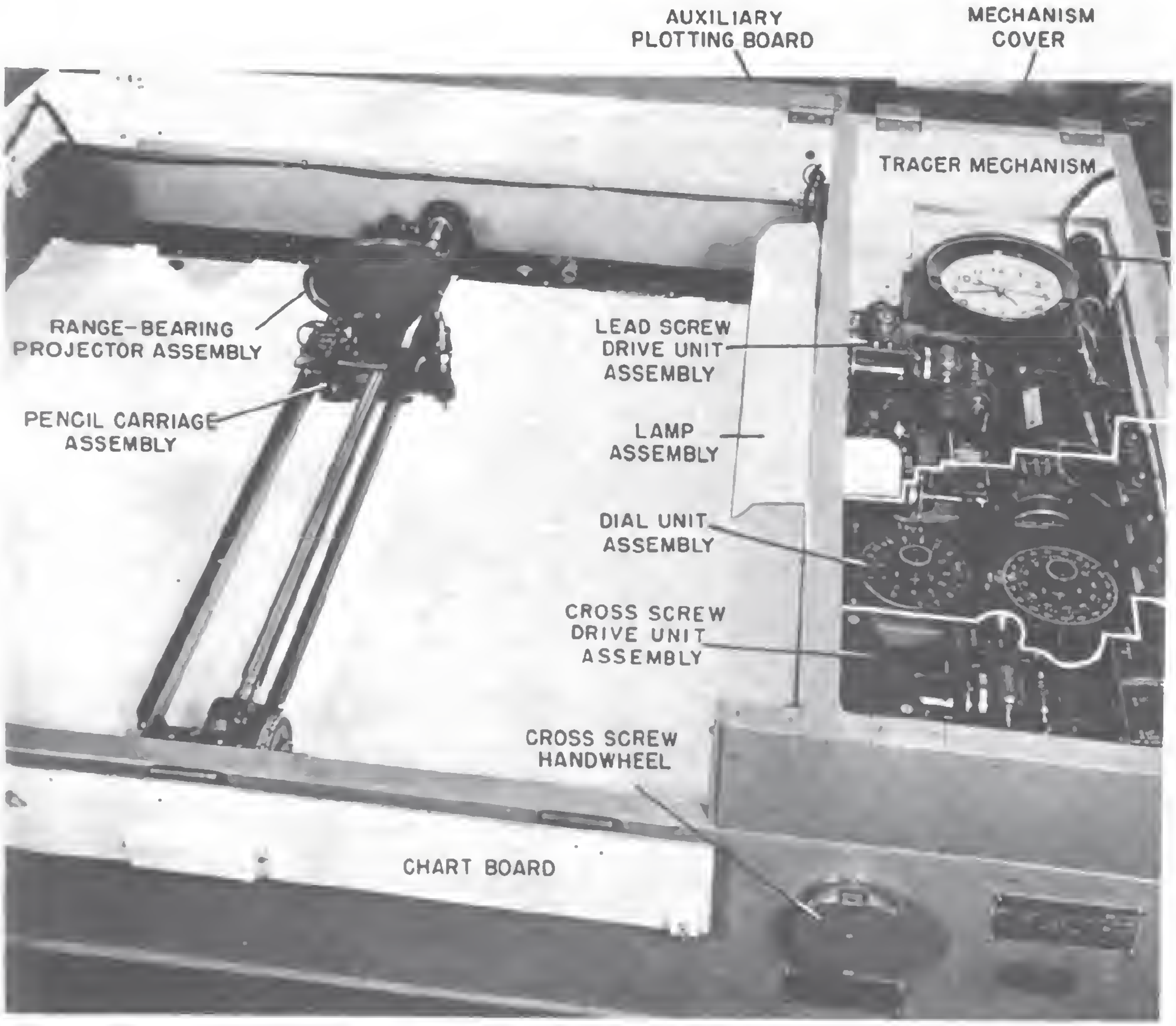

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Figure 7-6.—Dead reckoning tracer with auxiliary plotting board.

dial unit assembly of the DRI is also included in this mechanism. The north DRA transmitter actuates a receiver in the cross screw drive assembly, and the east DRA transmitter actuates a receiver in the lead screw drive assembly.

The cross screw drive unit assembly (fig. 7-5) consists of a receiver, X1, geared to the fluted shaft, Y, through a variable speed mechanism, Z1, and the standard-200 yd in. shaft. The variable speed mechanism and gear shift assembly provide a means of changing the latitude scale to which the ship's course can be plotted from the standard-200 yd/in. scale to the 1/4 to 1 mi/in., 1 to 4 mi/in., or 4 to 16 mi/in. scales.

The 200 yd/in. tracking scale is provided through a system of gearing that bypasses the variable speed friction drive assemblies that are employed when plotting to any of the other scales. To select the 200 yd/in. scale, the STANDARD-200 yd/in. gear shift is set in the 200 yd/in. position. In this position the variable speed friction drive assemblies rotate but do not

affect the 200 yd/in. tracking because no load is placed on the respective cluster gear bracket assemblies. To select any one of the three tracking scales, 1/4 to 1 mi/in., 1 to 4 mi/in., or 4 to 16 mi/in., the STANDARD-200 yd/in. gear shift is set in the STANDARD position, and the 3-position miles per inch gear shift is set to the desired range scale. This connects the variable speed friction drive assembly to the fluted shaft, Y, through the selected gear ratio. A final adjustment allows any scale within the selected range to be used by a fine adjustment handle on the variable speed assembly. The handle moves the adjustable drive roller (connected to the rotor of receiver X1 through gears) along its axis of rotation to vary the distance of the drive roller from the center of the friction disk. A scale graduated in miles per inch is provided with a vernier dial graduated in hundredths of a mile per inch for fine adjustments.

The friction disk that is driven by the cross screw receiver, X1, drives the fluted shaft, Y, through gears. The rotation of this shaft is transmitted to the cross screw, K1, by two bevel gears H1 on the pencil carriage assembly, J2. This action moves the clasp nut attached to the pencil carrier, J1. The bevel gears and the cross screw are free to move along the fluted shaft while the shaft is rotating.

The lead screw drive unit assembly (fig. 7-5) consists of a receiver, X2, that is geared to the lead screw, K2, through a variable speed mechanism, Z2, and the STANDARD-200 yd/in. gear shift. This variable speed mechanism and gear shift assembly are similar to those described in the cross screw drive unit assembly. They provide a means of changing the longitude scale to which the ship's course can be plotted from the 200 yd/in. scale to the 1/4 to 1 mi/in., 1 to 4 mi/in., or 4 to 16 mi/in. scales.

The friction disk that is driven by the lead screw receiver, X2 drives the lead screw, K2, through gears. The rotation of the lead screw, K2, moves the entire pencil carriage assembly, J2, along the tracking board. The cross screw, K1, is supported by an assembly that is geared to the lead screw, K2, by a clasp nut. As the receiver, X2, turns the lead screw, K2, the cross screw, K1, is moved to the right or left across the table, depending on the direction of rotation of X2. At the same time as the receiver, X1, turns the cross screw, K1, the pencil carrier, J1, is moved up or down, depending on the direction of rotation of X1.

Thus, as the lead screw and the cross screw are driven by their receivers in response to the impulses received from the DRA, the north and east components of the ship's motion are transmitted to the pencil. This action causes the pencil to move horizontally and vertically across the tracking board to trace a line that is the resultant of these components of the ship's travel. On a north or south course, only the cross screw is turned to trace a vertical line. On an east or west course, only the lead screw is turned to trace a horizontal line. On any other course, both the cross screw and the lead screw are turned to trace a line that bears the same relation to a vertical line as the ship's course bears to the meridian. The line represents, to scale, the actual course traveled by the ship.

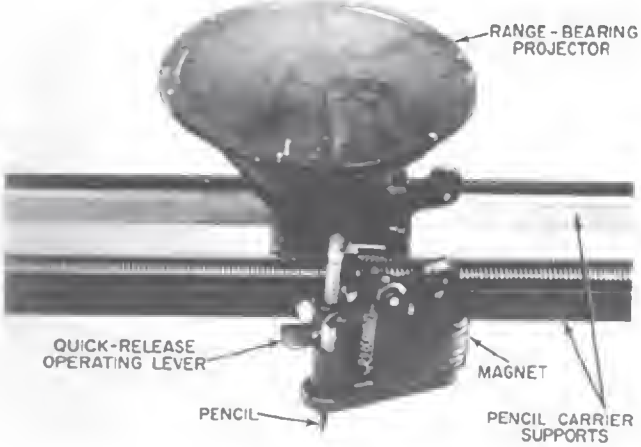
A component tracking (interchange) switch, Z, is provided so that the north and east component inputs from the DRA can be interchanged to shift the plotting axes. This arrangement permits using the longer dimension of the tracking table as either north or east, depending on whether the ship's course is predominantly north-south or east-west. However, it is usually preferable to operate the DRT with the north component, actuating the cross screw, K1 (long dimension, east), as illustrated by the gear diagram in figure 7-5. Roller carriages E1 are provided to keep the pencil carriage assembly, J2, alined with the table.

The clasp nuts that drive the cross screw, K1, and the lead screw, K2, to transfer motion to the pencil carriage, J1, and the pencil carriage, J2, can be released. This arrangement permits moving the pencil independently of the screws to any desired position on the table. When they reach the end of the screws the clasp nuts disengage automatically, to prevent damage to the instrument.

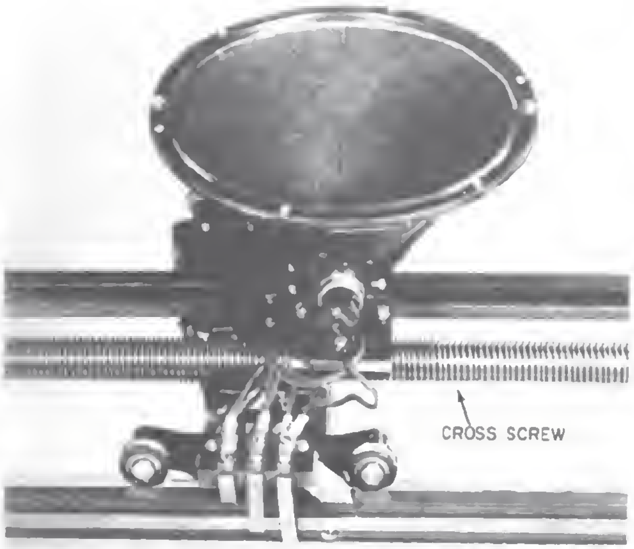
CHART BOARD

The chart board consists of a recessed plotting surface in the left-hand section of the DRT case below the pencil carrier assembly (fig. 7-6). The pencil automatically traces the movements of the ship on a chart inserted on the plotting surface.

The pencil carrier assembly, J1, is illustrated in figure 7-7. The pencil carrier assembly is supported by the pencil carriage assembly and includes the pencil, the pencil magnet, and the range-bearing projector. The



A. FRONT VIEW



B. REAR VIEW

Figure 7-7.—DRT pencil carrier assembly.
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pencil magnet is actuated by means of a clock-driven switch that energizes the pencil-magnet circuit at predetermined intervals. This action causes the magnet to lift the pencil from the chart periodically to omit the trace to facilitate interpreting the plot. The range-bearing projector (plotting light) is mounted on the pencil carrier for use in conjunction with the auxiliary plotting board to indicate the (own) ship's position at all times.

The pencil carrier is mounted on ball bearing rollers that travel in grooves provided in two supports located on either side of the cross screw (fig. 7-7A). These supports are part of the pencil carriage assembly and are therefore independent of the cross screw. Thus, the only contact the pencil carrier makes with the cross screw is through the threaded nut that converts the rotary motion of the cross screw into linear motion of the pencil and range-bearing projector.

The pencil can be set to any position within 0.1 in. of a designated point by two operating levers that actuate the quick-release nuts that run against the cross screw drive and the lead screw drive. These levers can be reached either through the side access doors in the DRT case, or by lifting the plotting board cover.

Two reset handwheels are provided for more precise setting of the pencil than to 0.1 in. (fig. 7-5). The reset handwheel mounted adjacent to the tracking-mechanism end of the case moves the pencil carrier along the cross-screw axis; whereas, the reset handwheel mounted at the chart-board end of the case moves the entire carriage assembly along the lead-screw axis.

The pencil magnet and the range-bearing projector light are connected to three sliding contacts (on the pencil carrier) that bear on a three-bus trolley circuit mounted on one of the pencil-carrier supports (fig. 7-7B). The third bus is provided so that the pencil magnet and the range-bearing projector light can be used either separately or simultaneously. Three brushes, located at the end of the three-bus trolley circuit opposite the bevel gears, bear on three stationary contact rails that are supplied with the ship's 120-volt, d-c power.

General illumination for the DRT is provided by lamps located inside the chart-board and the tracking-mechanism areas. The lighting supply, which can be either a-c or d-c, is connected to a terminal block mounted on the partition between the chart board and tracking mechanism. A variable resistor in series with this circuit controls the intensity of illumination.

AUXILIARY PLOTTING BOARD

The auxiliary plotting board is a large glass surface mounted in a frame that is hinged to the DRT case (fig. 7-6). This plotting surface is furnished in conjunction with the DRT for plotting ranges and bearings of surface targets obtained from points along the (own) ship's course. It consists of a (1) flush top plotting surface to facilitate the use of a drafting machine (universal), and (2) range-bearing projector assembly mounted on the pencil carrier.

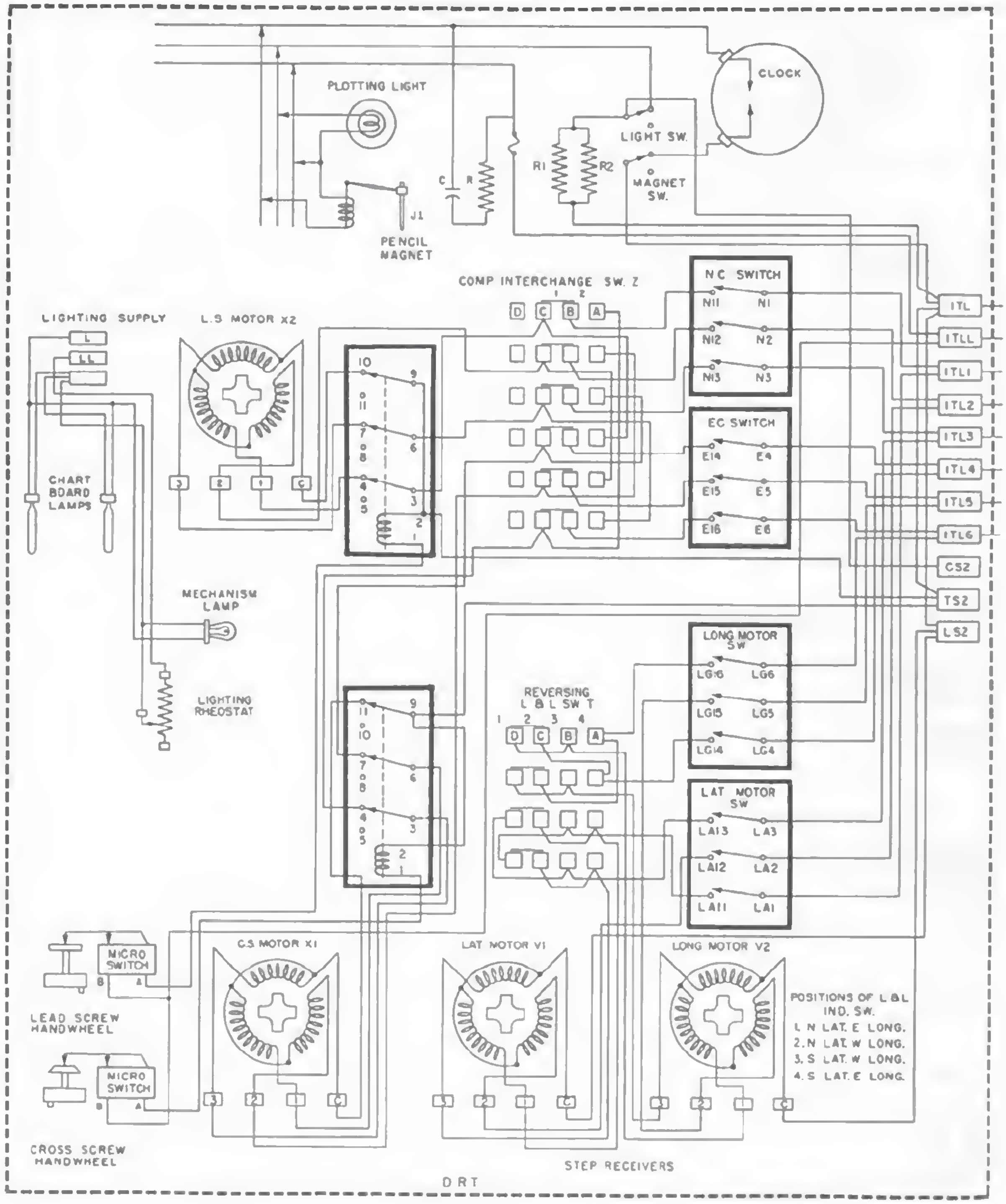

Figure 7-8A.—Dead reckoning system wiring diagram.

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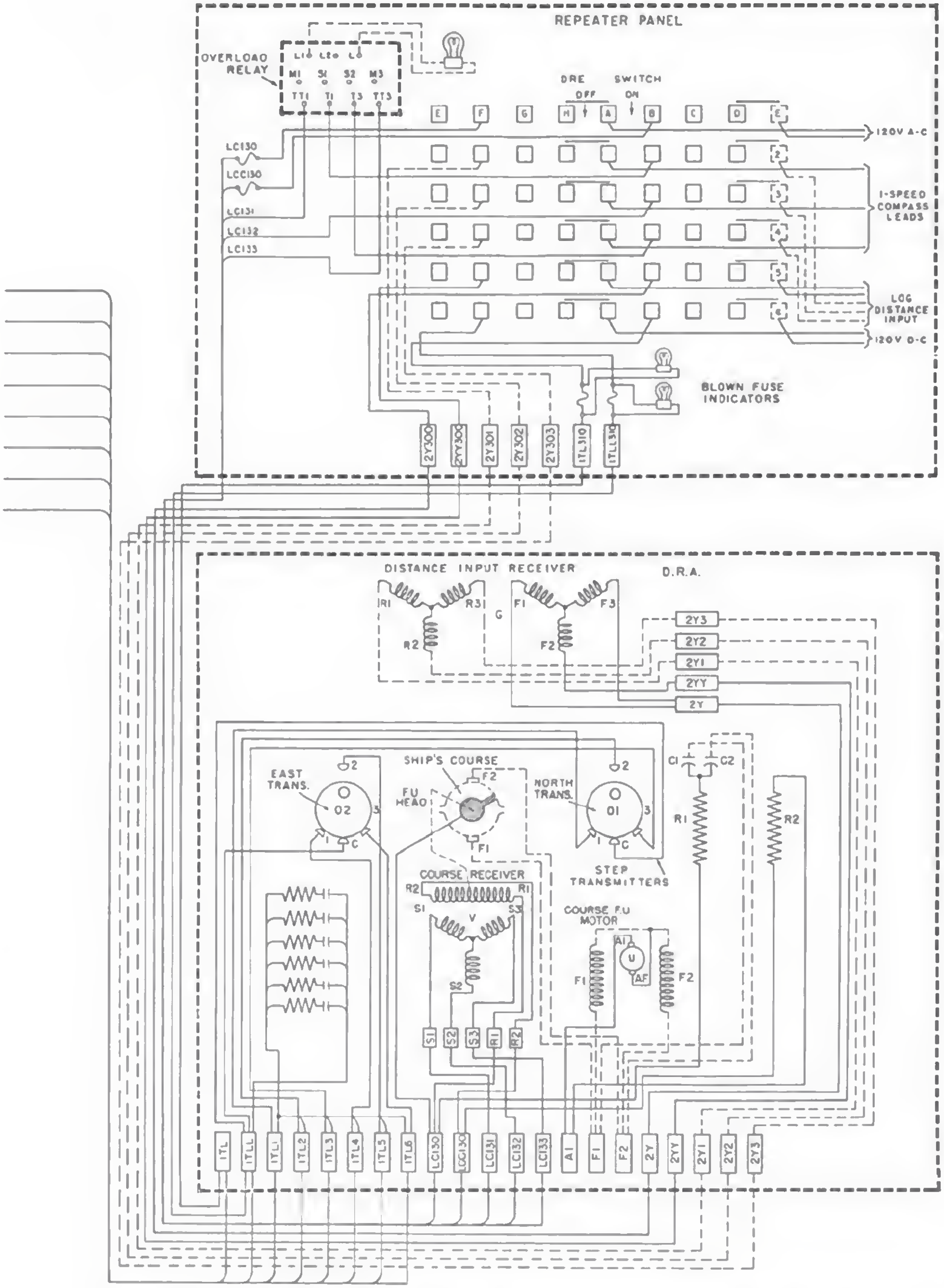

Figure 7-8B.—Dead reckoning system wiring diagram—continued.

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The range-bearing projector includes a light that projects an image on an appropriate chart placed on the plotting board. (fig. 7-7). This image consists of five uniformly spaced concentric circles with a dot in the center of the innermost circle denoting the (own) ship's position. The plotting scale must be the same as the tracking scale for which the tracking mechanism is adjusted.

The range and bearing of a target with respect to the (own) ship is plotted from the center dot of the projected image. If the plotted radius is less than 5 in., the range and bearing will fall within the projected area. However, if the plotted radius exceeds 5 in., it is necessary to use a drafting machine.

The drafting machine is mounted on the glass plotting surface. It consists of a range ruler mounted from the center of a compass rose that is attached to a linked arm, and can be moved to any position on the plotting board. The range ruler can be set on any required bearing and when locked in place will remain on the same bearing irrespective of the movement of the compass rose.

OPERATION AND MAINTENANCE

The wiring diagram of the dead reckoning system is illustrated in figure 7-8. This system includes the (1) distance transmitter circuits, 2Y; (2) course followup circuits, LC; (3) step transmitter circuits, 1TL; and (4) pencil-magnet and projector-light circuits.

The DRE switch on the repeater panel is an ON-OFF switch. When this switch is closed, the rotor of the input course synchro receiver and the course followup motor are energized from the ship's single-phase, 120-volt, 60-cycle power supply; the 1-speed transmitter on the master compass provides an indication of the ship's course; the underwater log transmitter provides an indication of the ship's distance; and the step transmitters, step receivers, and pencil-magnet circuit are energized from the ship's d-c 120-volt power supply.

DISTANCE TRANSMITTER CIRCUITS

The input to the log distance transmitter circuits of the dead reckoning equipment is fed from the log distance transmitter to the DRE switch on the repeater panel (fig. 7-8). When this switch is closed, the stator leads, S1, S2, and S3, of the log distance transmitter are connected respectively to the terminals, 2Y301. 2Y302, and 2Y303, on the repeater panel. These terminals are connected to the terminals, 2Y1. 2Y2, and 2Y3, respectively, in the DRA.

The distance input receiver, G, in the DRA is a differential-type synchro having wye-connected stator windings and wye-connected rotor windings. The rotor leads, R1, R2, and R3, of this differential synchro receiver are connected. respectively, to the stator leads, S1, S2, and S3, of the log distance transmitter. The stator leads, F1, F2, and F3, of the differential synchro receiver (F1 and F3 connected together) are connected respectively to the rotor leads, R1 and R2, of the log distance transmitter, which is energized through the terminals, 2Y and 2YY. in the DRA from the ship's single-phase, 120-volt, 60-cycle power. This arrangement provides the necessary field excitation to produce motor torque so that the receiver matches the rotation of the log distance transmitter. The differential synchro receiver is employed instead of a conventional synchro receiver to obtain more reliable operation. If the primary power supply to the synchro differential receiver should fail, the torque and output would drop to values insufficient to operate the receiver: whereas, in an ordinary synchro receiver, the salient pole rotor might develop sufficient torque to lock in at either 0° or 180°. Thus, the system might operate with an error of 180°.

COURSE FOLLOWUP CIRCUITS

The input to the course followup circuits of the dead reckoning equipment is fed from the 1-speed transmitter on the master compass to the DRE switch on the repeater panel (fig. 7-8). When this switch is closed, the 1-speed transmitter stator leads, S1, S2, and S3, are connected to the terminals, LC131, LC132, and LC133, in the DRA. These terminals are connected respectively to the stator leads, S1, S2. and S3, of the course synchro receiver, V, in the DRA. The rotor leads, R1 and R2, of this course synchro receiver are connected, respectively, to the terminals, LC130 and LCC130 (in the DRA), which are energized from the ship's single-phase, 120-volt, 60-cycle power through the DRE switch on the repeater panel. An overload relay in the stator circuit between the DRE switch and the fuses on the repeater panel will indicate improper functioning of the course input synchro receiver, V, in the DRA by lighting a signal light on the repeater panel.

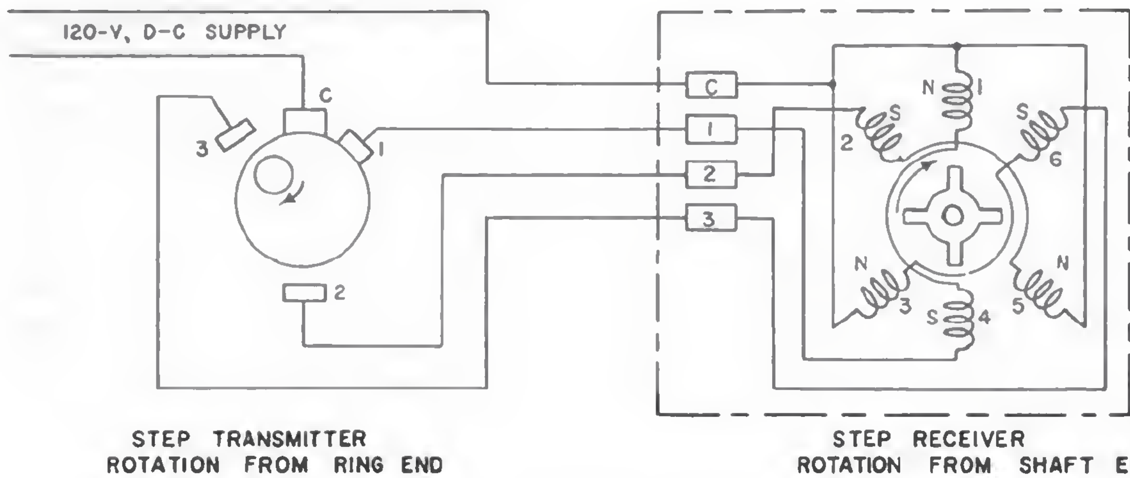

Figure 7-9.—Step transmitter-receiver circuit.

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The course followup motor, U, in the DRA is an a-c commutator-type series motor. It is energized from terminals LC130 and LCC130. Terminal LC130 is connected to the contact arm mounted on the rotor shaft of the course synchro receiver, V. This arm can contact either split ring segment F1 or F2 in the followup head, depending on the direction of rotation of the course followup motor, U. These ring segments are connected, respectively, to the field terminals, F1 and F2, of the course followup motor. The motor field windings are arranged so that when the contact arm is on one split ring segment, current flows through one winding and the motor turns in one direction. Conversely, when the contact arm is on the other split ring segment, current flows through the other winding and the motor turns in the opposite direction. The armature of the followup motor is in series with the energized field. The other side of the armature is connected through terminal A1 to terminal LCC130 through R2. Resistor R2 limits the current through the motor. Resistor R1, in series with capacitors C1 and C2 that are connected, respectively, to leads F1 and F2, prevents sparking at the contacts in the split ring assembly.

STEP TRANSMITTER CIRCUITS

The north and east step transmitters, O1 and O2, in the DRA convey the north-south and east-west components of the ship's travel from the roller carriages, P1 and P2, to the pencil, J1, in the DRT and to the latitude and longitude dial receivers, V1 and V2, in the DRI.

A simple step transmitter-receiver circuit is illustrated in figure 7-9. The circuit is energized from the ship's 120-volt, d-c power. The step transmitter includes an eccentric arranged to operate three contacts in succession to close one side of the line, and a common contact that remains closed to complete the circuit. These three contacts energize coils in the step receiver in a definite sequence to cause the receiver rotor to rotate an amount proportional to the rotation of the transmitter. The rotor has four salient poles without windings.

The three transmitter contacts, 1, 2, and 3, are spaced 120° apart. Each is adjusted to make contact during 180° of the revolution of the eccentric to allow a 60° overlap in the closing of adjacent contacts. Each transmitter contact is connected to a pair of diametrically opposite coils in the six-pole step receiver.

When transmitter contact 1 closes to energize receiver coils 1 and 4, the closest pair of armature poles line up with these coils. Transmitter contact 2 closes 60° before contact 1 opens and energizes receiver coils 2 and 5 to make coils 1 and 2 opposite in polarity. This condition causes the receiver armature to rotate 15° in a clockwise direction, tending to line up the closest pair of adjacent poles with the axes of coils 1 and 2. Next, transmitter contact 1 opens and the receiver armature rotates another 15° clockwise to line up the closest pair

of armature poles with the axes of coils 2 and 5. A similar sequence occurs when transmitter contact 3 closes and contact 2 opens 60° later. Thus, a 60° rotation of the transmitter causes the receiver to rotate 15°, resulting in a 4 to 1 ratio between the revolutions of the transmitter and receiver.

The step transmitter circuits of the dead reckoning equipment are supplied from the ship's 120-volt, d-c power to the DRE switch on the repeater panel (fig. 7-8). When this switch is closed, 120-volt, d-c power is supplied to terminals 1TL310 and 1TLL310 on the repeater panel. These terminals are connected to terminals 1TL and 1TLL respectively, in the DRA. Terminal 1TLL is connected to the common terminal, C, of both the north and east transmitters, 01 and 02. The return circuits from the transmitter contacts are to terminals 1TL1 to 1TL6, inclusive. These six transmitter terminals are connected to a resistance and capacitor bank that has a common return to terminal 1TLL. This resistance-capacitance bank is provided to prevent sparking of the transmitter contacts.

The DRA terminals, 1TL, 1TLL, and 1TL1 to 1TL6, inclusive, are connected to similar marked terminals in the DRT (fig. 7-8). The cross screw and lead screw receivers, X1 and X2, are connected to the terminals, 1TL1, to 1TL6, inclusive, through the component interchange switch, Z. Terminals 1TL1, 1TL2, and 1TL3 provide the north-south components of the ship's travel, and terminals 1TL4, 1TL5, and 1TL6 provide the east-west components of the ship's travel. The common terminals, C, of both receivers X1 and X2 are connected to terminal 1TL through terminal TS2 in the DRT.

A relay in series with each of the receivers, X1 and X2, is energized from terminals 1TL and 1TLL with the d-c supply through microswitches mounted adjacent to the cross screw and lead screw reset handwheels. These relays are provided to automatically open the circuits of the pencil-drive receivers when using the reset handwheels. When either handwheel is operated, the thrust required to mesh the reset gears will close the microswitch in the circuit of the associated relay coil. This action causes the relay armature to open the contacts in series with the associated pencil-drive receiver.

The latitude receiver, V1, connected to terminals 1TL1, 1TL2, and 1TL3, and the longitude receiver, V2, connected to terminals 1TL4, 1TL5, and 1TL6 are connected through the (dial) reversing switch, T. The common terminal, C, of both the latitude and longitude receivers is connected to terminal 1TL through terminal LS2.

It is usually preferable to operate the DRT component interchange switch, Z, in position 2. In this position the north component actuates the cross screw receiver, X1, and the east component actuates the lead screw receiver, X2. Thus, as the ship travels in a northerly direction, the pencil will move away from the fluted-shaft side of the case. Conversely, as the ship travels in an easterly direction, the entire pencil carriage assembly will move toward the tracking-mechanism end of the case.

In some installations it may be preferable to plot northerly travel of the ship along the lead screw axis. This is accomplished by setting the component interchange switch, Z, in position 1 to shift the plotting axes 90° counterclockwise. In this position the north component actuates the lead screw receiver, X2, and the east component actuates the cross screw receiver, X1. In either position the common terminal, C, of the receivers is connected to the 1TL terminal of the d-c supply through the respective relays.

Four 3-pole switches are provided in the receiver circuits (fig. 7-8) so that the receivers, X1, X2, V1 or V2, can be turned on or off independently while the equipment is in operation.

PENCIL-MAGNET AND PROJECTOR-LIGHT CIRCUITS

The pencil-magnet and range-bearing projector-light circuits are energized from the ship's 120-volt, d-c power through terminals 1TL, 1TLL, and CS2 in the DRT (fig. 7-8).

When the pencil-magnet switch is closed, the circuit from terminal 1TL includes the magnet switch, clock, pencil magnet, fuse, and terminal 1TLL. A capacitor, C, and resistor, R, that are connected across the magnet coil reduce sparking at the clock contacts.

When the light switch is closed, the circuit from terminal 1TL includes the parallel-connected resistors, R1 and R2, the light switch, the plotting light, the fuse, and terminal 1TLL.

When the dead reckoning system is placed in operation, all switches should be in the OFF position, and the minute dials of the latitude and

longitude dials of the DRT should be set to indicate the latitude and longitude of the ship. The latitude and longitude receiver switches should be turned to the ON position.

An appropriate chart on which the ship's course is to be plotted is tacked on the chart board and the desired reference lines are drawn. The course to be plotted should be considered, and the pencil should be placed so that it will not run off the chart on one side and leave a large unused section on the other side of the chart. The pencil is located by disengaging the clasp nuts on the pencil carriage and moving the pencil to the desired location. The north and east component receiver switches are now turned to the ON position.

The miles-per-inch setting of the DRT, for both the north and east components, should be adjusted to a value consistent with the length of the course to be plotted and the space available on the chart. Both settings should be adjusted to the same miles-per-inch scale to avoid the necessity of computing the number of miles for a given course.

The latitude and longitude (dial) reversing switch, T, of the DRT is set to the proper earth's quadrant in which the ship is operating. The latitude and longitude receivers will rotate in the proper direction, causing the latitude and longitude dials to indicate correctly. The proper position of this switch must be selected when crossing the equator the 0° meridian, or the 180° meridian.

The component interchange switch, Z, of the DRT is set to the desired plotting axes as indicated on the nameplate under the switch handle. As previously stated, this switch provides for shifting the plotting axes at right angles to each other to orient the north in either of the two available directions on the chart board.

The clock switch of the DRT can be turned to the OFF or ON position, depending on whether or not it is desired to plot the course with a time element.

When the DRE switch is turned to the ON position the course receiver takes its proper position, and the followup motor brings the crank arms to their proper position. The step receivers in the DRT and the distance input receiver in the DRA revolve in synchronism with their respective transmitters.

ANALYSIS AND EVALUATION OF TESTS

The maintenance of IC equipment requires the ability of the supervisor to quickly trace failures to their sources. A leader should learn effect-to-cause reasoning and its application. The leading IC may readily evaluate troubles in the DRE because they usually fall into three main groups: (1) an effect of no performance is caused generally by lack of electrical power; (2) erratic action may be caused by mechanical or electrical failures; and (3) inaccurate performance is usually traced to improper calibration.

Condition With No Power

In the event of electrical troubles the most important thing to remember is that the DRE was properly wired and tested before installation and checked again afterward. Therefore, permit no alterations in wiring. The most common cause of electrical failures are loose connections, blown fuses, and dirty or worn motor or step transmitter brushes. Unless there is reason to believe that the trouble is in a specific section of the DRE, it is well to begin at the source of the power supply and test the circuit progressively with a test lamp or meter until the trouble is located.

Erratic Mechanical Actions

Extreme care should be taken to examine all drive discs and other exposed metal parts to ensure that they are properly lubricated. Special care should be directed to the friction drive discs and rollers in the analyzer and in the tracer, keeping them cleaned and oiled with a light coating of mineral oil which prevents rust or corrosion. Otherwise, erratic mechanical actions will be experienced.

Erratic Electrical Actions

It is important that the distance input motor starts immediately as the DRE switch is turned on. Otherwise, undue heating of the motor windings may result. Should the motor fail to start immediately, turn off the DRE switch and follow instructions outlined in the manufacturer's manual for clearing such faults.

Erratic action of the step motors may be caused by open circuits, worn transmitter brushes, or shorted capacitors. Test those parts as directed in the specific technical manual where information is given for rapidly evaluating the condition of suspected items. As with all IC service work, the knowledge of

basic principles must be supplemented by practical experience. The leading IC should be confident about his evaluation of suspected parts being good or bad. When in doubt, a suspected part should be replaced with new material.

CHAPTER 8

CLOSED CIRCUIT TELEVISION

The closed circuit television system makes it possible for shipboard personnel to view or monitor various operations at remote locations and to exchange vital information rapidly. A representative system (fig. 8-1) includes a camera, system control cabinet, electronic equipment cabinet, and one or more viewers. This system provides better detail than commercial television because it uses interlaced scanning at 875 lines per frame instead of 525 lines per frame, and the line rate is 26,250 cps for closed circuit TV instead of 15,750 cps as for commercial TV.

Figure 8-2 shows the different components of the system that are housed in the electronic equipment cabinet.

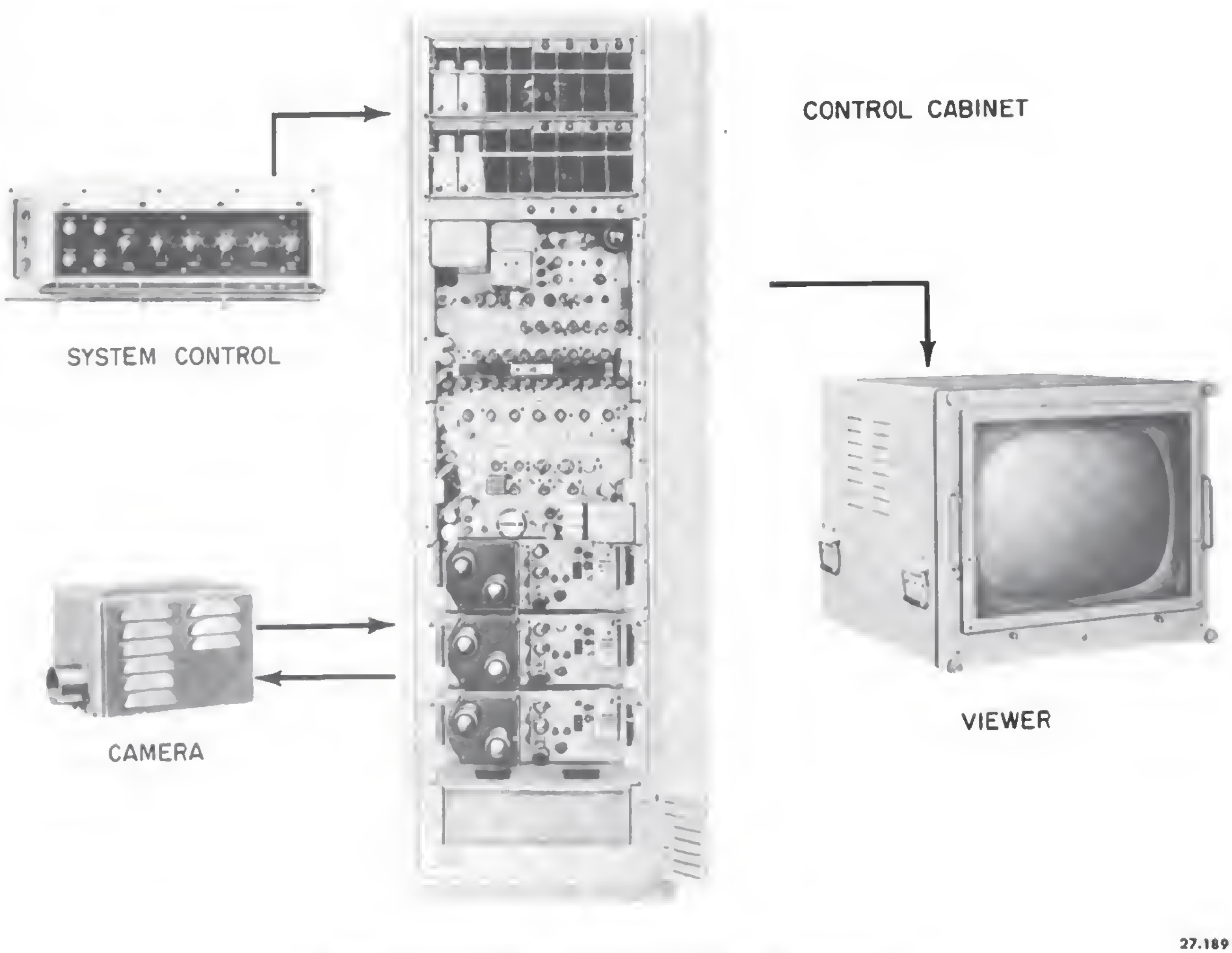

Figure 8-1.—Closed circuit television system.

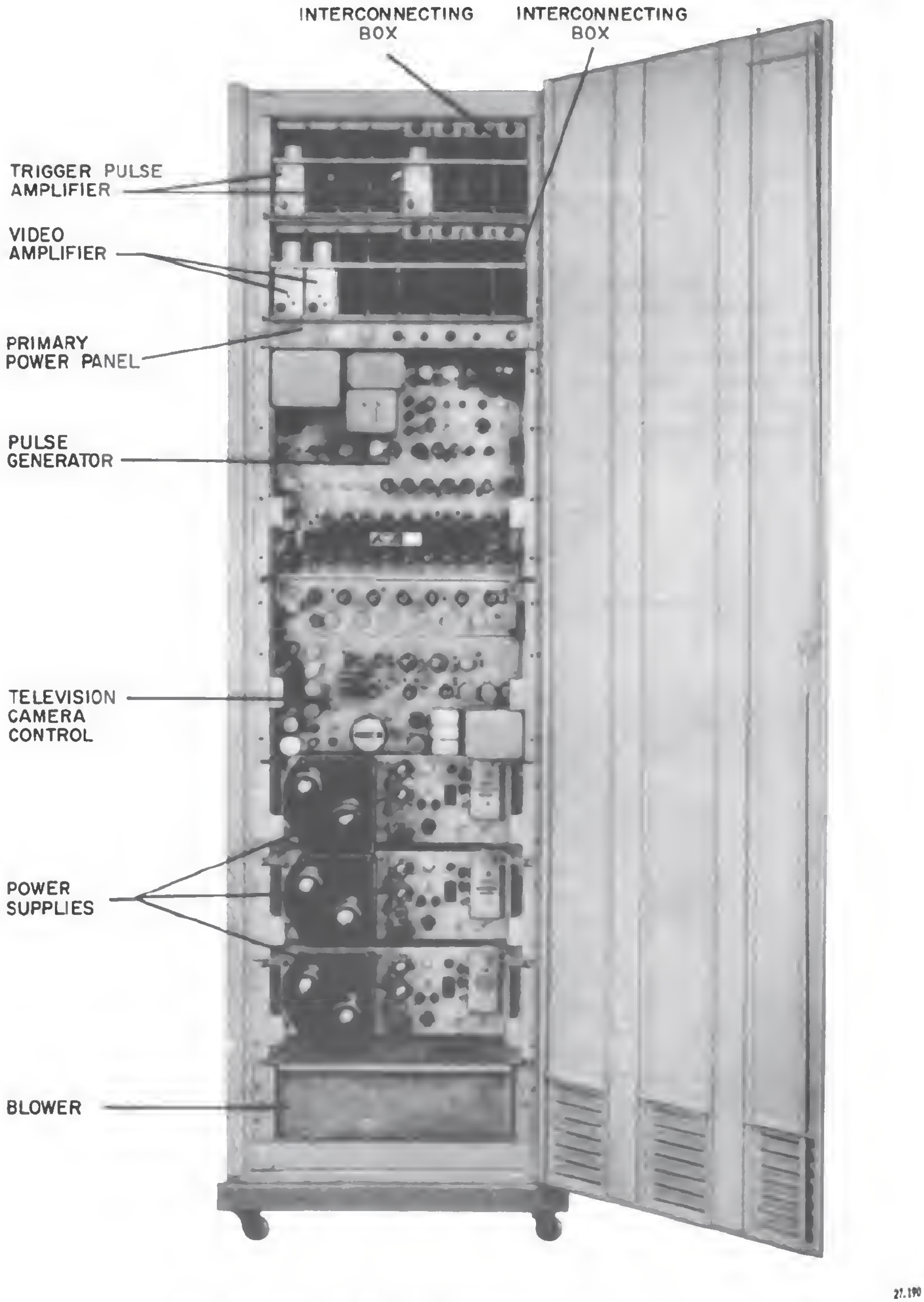

Figure 8-2.—Electronic equipment cabinet.

The interconnecting cables between the various units are shown in figure 8-3.

The fixed-focus television camera is fastened to the overhead and is aimed at the CIC plotting board. The video output of the camera can be supplied to a maximum of eight remote viewers. The camera has one manually focused lens and, once the lens is adjusted, it is not normally changed.

The block diagram (fig. 8-4) shows the television system signal distribution paths. The system functions in the following manner: a television camera lens picks up and converts a picture to a video signal. The signal is then amplified by a television camera control unit, and a blanking pulse is inserted from a pulse generator. The blanking and video signals are applied to video distribution amplifiers which pass them on to a television viewer.

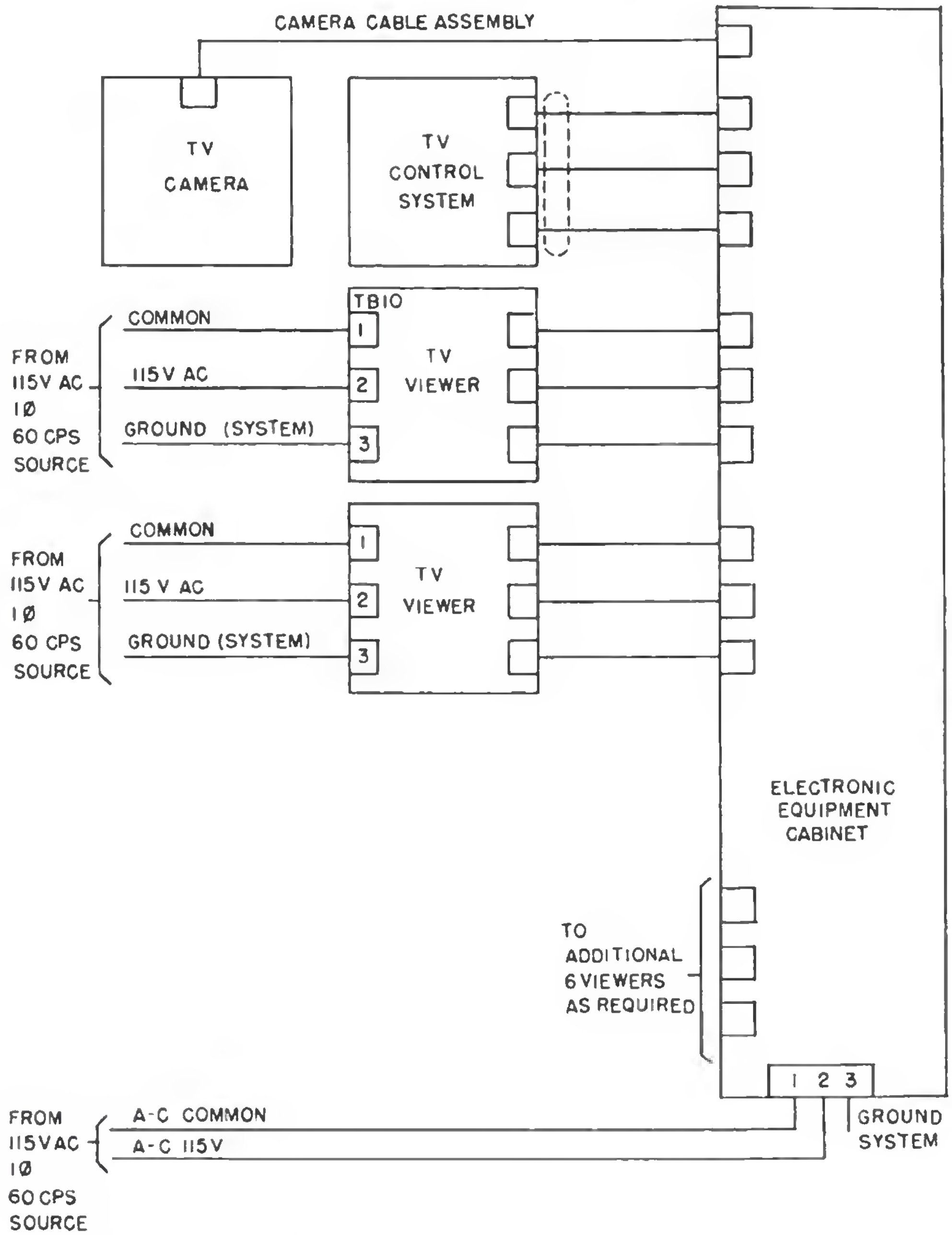

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Figure 8-3.—Closed circuit television interconnecting cables.

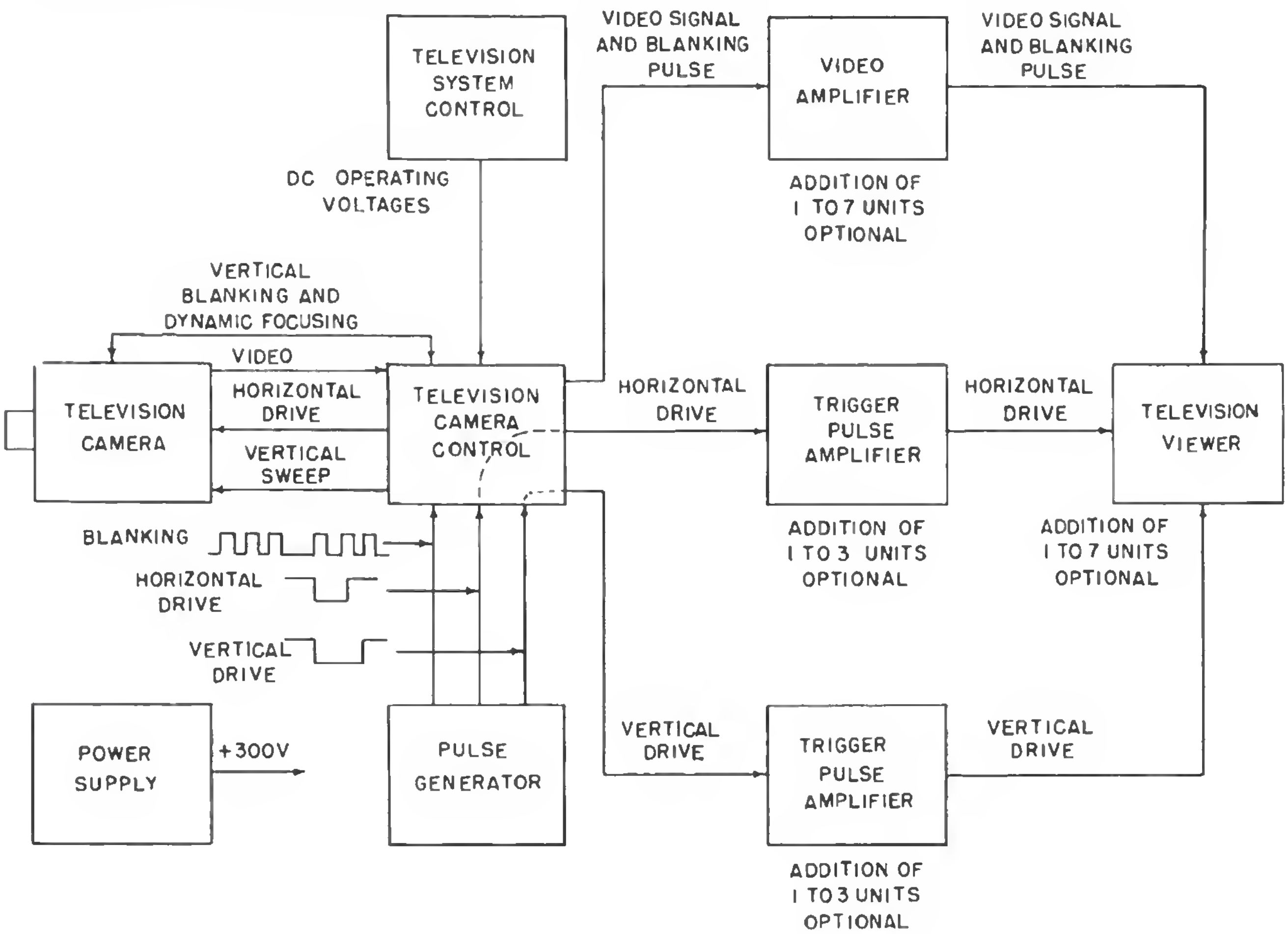

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Figure 8-4.—Overall block diagram.

Horizontal and vertical pulses are also supplied by the pulse generator. These horizontal and vertical pulses are fed to a television camera control unit and then to the viewer via a trigger pulse amplifier.

PULSE GENERATOR

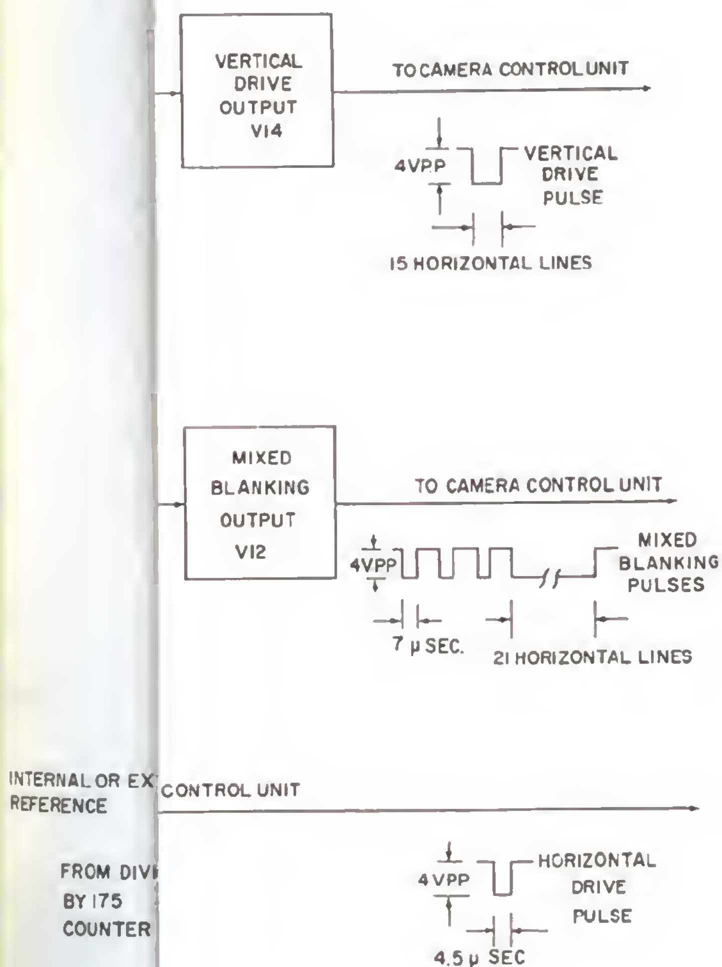
The pulse generator produces all the synchronizing waveforms necessary in the development of the complete video signal for the television system. These signals are the horizontal and vertical drive pulses which are supplied to the scanning and viewer circuits; and the blanking waveform which is combined with the camera video to make up the composite video signal. The block diagram (fig. 8-5) shows the signal paths of the pulse generator section.

The pulse generator is entirely self-contained and has 3 major sections: the master oscillator, the pulse generators, and the power supply (not shown).

MASTER OSCILLATOR

The master oscillator, V3, is a tuned L-C type that operates at twice the horizontal frequency, and can be switched to lock with either the a-c supply or an external reference, or it can be switched to crystal control or free-running conditions. The output of V3 is used to trigger a blocking oscillator in the pulse forming section.

With a selector switch (not shown) reactance tube V4 can be connected across the master oscillator tank circuit so that V4 acts as an inductive reactance. The magnitude of the inductive reactance is determined by the grid potential of V4.



VERTICAL DRIVE OUTPUT V14
TO CAMERA CONTROL UNIT
4VPP
VERTICAL DRIVE PULSE
15 HORIZONTAL LINES
MIXED BLANKING OUTPUT V12
TO CAMERA CONTROL UNIT
4VPP
MIXED BLANKING PULSES
7 μ SEC.
21 HORIZONTAL LINES
INTERNAL OR EX
REFERENCE
CONTROL UNIT
FROM DIV
BY 175
COUNTER
4 VPP
HORIZONTAL DRIVE PULSE
4.5 μ SEC

FREQUENCY LOCKING CIRCUITS

A bridge discriminator CR1 and CR2, twin diode V2, and reactance tube V4 (fig. 8-6) are arranged to form a frequency locking circuit. The purpose of the frequency locking circuit is to alter the master oscillator frequency to bring the divider voltage output into synchronism with the reference voltage.

The locking circuit functions as follows: The output of the main divider at field frequency is differentiated in the grid circuit of V1A. Short-duration pulses at field frequency are developed in the secondary of T1 and fed to points A and D of the bridge. These pulses cause the bridge rectifiers to conduct on alternate half cycles. When they conduct they act like a closed switch, allowing a sawtooth signal from B to ground to be sampled (developed) at the V4 input.

A 6.3-volt reference voltage from the power supply is applied via a step-up transformer and phase shifter to V1B. Differentiation takes place at the grid and a sawtooth output is developed at the plate. This output is applied to the bridge at B. The amplitude of the voltage developed at the plate of V1B is sampled at C during the conducting periods of the bridge, i.e., at a frequency of the divider output. When a difference in frequency occurs between the two inputs to the bridge network, a change in voltage is produced at the grid of reactance tube V4. The polarity of the discriminator output is such that the master oscillator frequency is changed to bring the divider voltage into synchronism with the reference voltage.

Provision is made for phase adjustment of the reference voltage before it is applied to the discriminator, so that field synchronism can be obtained with other equipment which is locked to the reference. A phase shift of approximately 180 degrees can be obtained by operating a selector switch (not shown) in the phase shift circuit.

PULSE FORMING SECTION

The output of the master oscillator V3 (fig. 8-7) is amplified by V11A. The output of V11A is differentiated and fed to the grid circuit of blocking oscillator V11B. A transformer (not shown) provides inductive coupling between the grid and plate circuits of V11B. The blocking oscillator load, which contains the delay line, is connected to the cathode of V11B.

When V11B conducts during the positive-going peaks of the differentiated output of V11A, short duration pulses at twice the horizontal frequency are transmitted down the delay line. The delay line is made up of series-connected m-derived, low-pass L-C sections having a total delay of approximately 10μ s, and is terminated in its characteristic impedance.

Trigger pulses, accurately related to one another in time, are taken from taps along the line. The output from the terminated end of the line is applied to the control grid of divider feed amplifier V21A.

MIXED BLANKING

The mixed blanking waveform is generated in the bistable multivibrator V9 (fig. 8-7) by applying the vertical blanking waveform and pulses which initiate the leading and trailing edges of the horizontal blanking pulse.

The circuit action is as follows: Twice horizontal frequency pulses corresponding to the leading edges of horizontal blanking are applied to V10; a divide by 2 gating waveform is taken from V20A (fig. 8-7) and applied to V10 through C29. Alternate pulses are suppressed and the negative-going output of V10 is applied to V9A and triggers that circuit, except during the vertical blanking periods.

Negative-going vertical blanking is fed from V19B to the junction of R32 and CR4 in the grid circuit of V9A, and holds that triode section in a nonconducting condition during the vertical blanking periods.

Timing pulses corresponding to the trailing edges of horizontal blanking are amplified and inverted by buffer stage V8A and then applied to the plate of V9A from the junction of R40 and CR5 through C34; alternates of these pulses are effective in resetting V9, except during the vertical blanking periods. Therefore, V9B conducts during the horizontal and vertical blanking periods and V9A conducts during the intervening periods. Diode CR3 acts as a d-c restorer. CR4 and CR5 help to obtain optimum operation of V9 by providing, in their respective circuits, a low impedance path to chassis between pulses. The positive-going output from V9A is applied to V13A.

HORIZIONTAL DRIVE

The horizontal drive waveform is generated in multivibrator V7 which is triggered by an

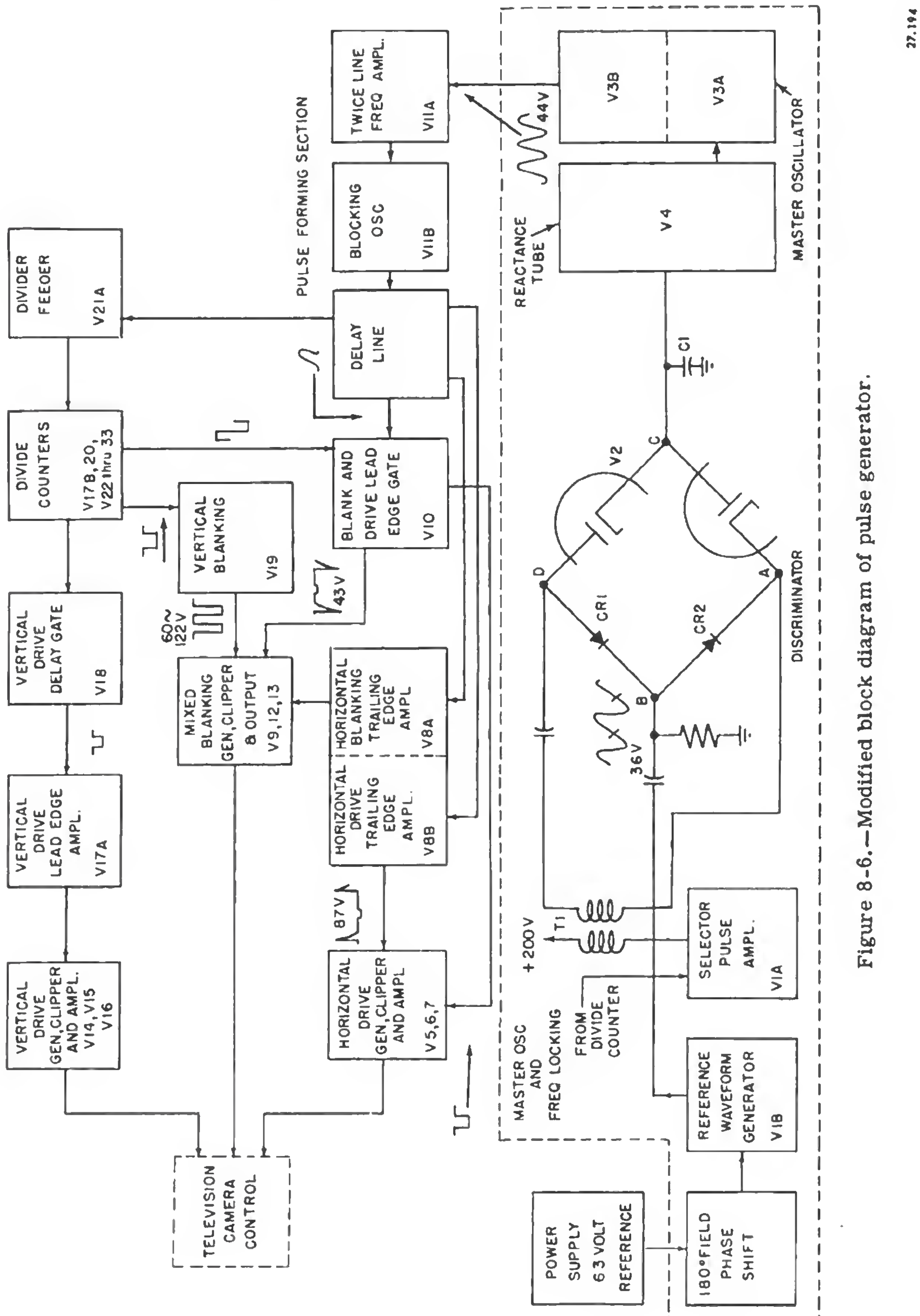


Figure 8-6.—Modified block diagram of pulse generator.

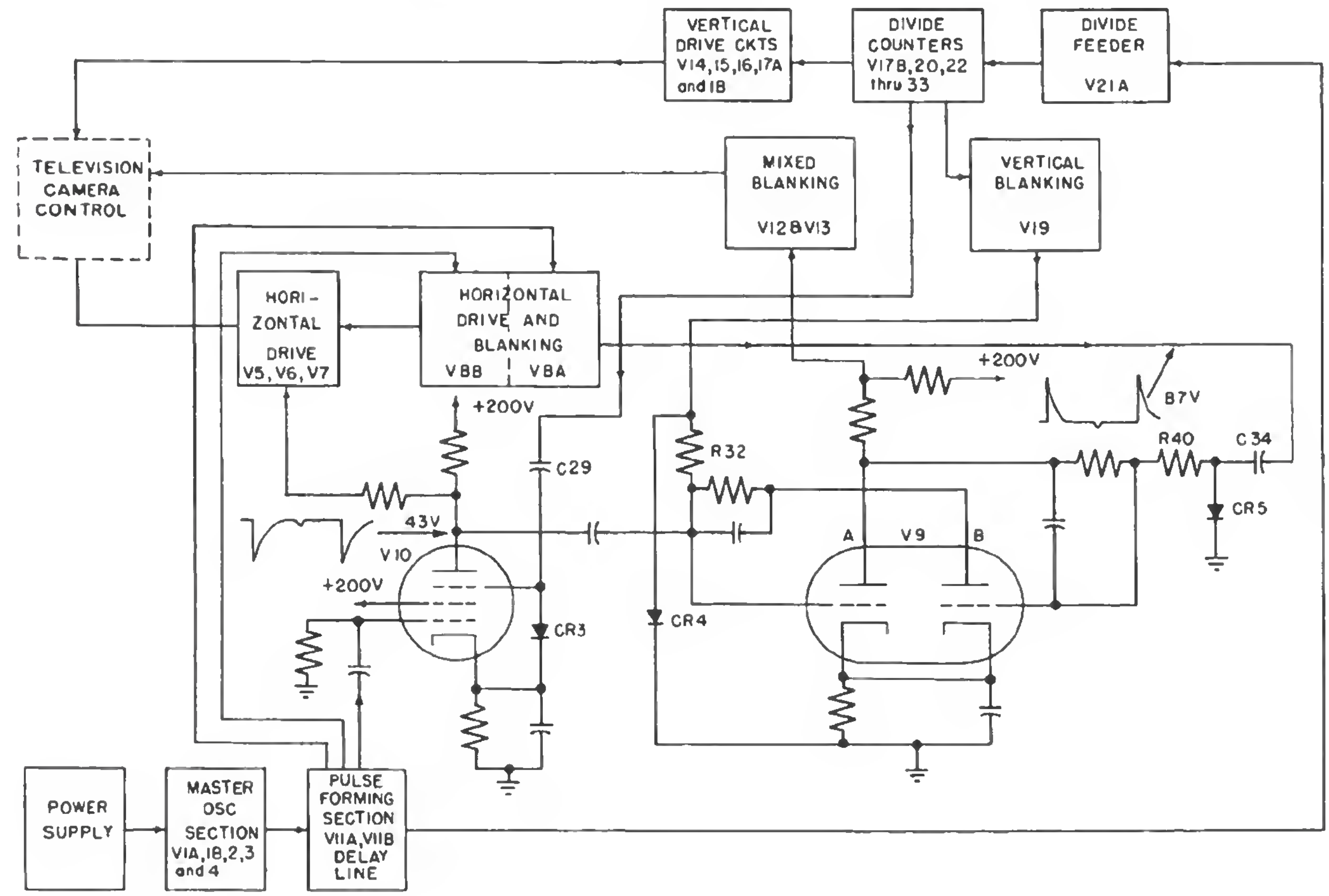


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Figure 8-7.—Modified block diagram of pulse generator with mixed blanking circuit.

output of V10 (fig. 8-7). The trigger pulse is applied through a one-way gate to V7A. Trailing edge pulses are taken from the delay line to the grid of V8B, which is biased to cutoff, and appear as negative-going pulses at the plate of V8B. The output of V8B is applied to V7B to reset that stage. The positive-going output of V7B is applied to V6A.

CLIPPER AND OUTPUT STAGES

The clipper circuit V6 automatically controls the amplitude of the final waveform (horizontal drive) so that pulses are delivered to the output amplifier V5 at a constant level. Both positive and negative clipping takes place in the clipper stage and the maximum and minimum values of output voltage taken from V6B are determined by the nonconductive and conductive states, respectively, of that tube. The negative horizontal drive output is fed to the camera control unit.

COUNTERS

The block diagram for the divide by 2 circuits is included in figure 8-5. Tube V20 is connected as a bistable multivibrator and the common grid circuits are triggered by a negative-going pulse from V21A. The output of V20B is a square waveform at the horizontal frequency and is used as a gating waveform to divide the pulse repetition frequency of certain delay line outputs by a factor of two. The divided output is fed to the blanking and drive leading edge gate V10. The output from the plate of V21A is fed to the grid of V33B.

MAIN DIVIDER

There are 11 dividers in the main divider chain. The first 3 dividers (V31 through V33) and the feedback amplifier V30 for the divide by 5 chain, and dividers V22 through V29 and the

feedback amplifier V17B for the divide by 175 chain, are shown in figure 8-5.

The main divider reduces the twice horizontal frequency input (applied to the grid of V33B) to field frequency. The main divider network operates in two sections. Frequency dividers, V31 through V33, form the first section, which provides one output pulse for each five input pulses. The second section is composed of dividers V22 through V29 and provides one output pulse for each 175 pulses of input from the first section. Because the two sections are in cascade, the overall count is 875.

Each divider is connected in a bistable multivibrator circuit. Each grid is triggered by the negative-going peaks of the differentiated output of the previous stage. Feedback pulses, similar negative-going, are taken from one stage in the chain and fed to the input of a previous section.

DIVIDE BY 5 COUNTER

Three bistable multivibrators (V33, V32, and V31) and a feedback amplifier V30 are used in the divide by 5 counter. The action is a little unusual because normally a counter consisting of three bistable multivibrators would give a count of 8.

In a divide by 5 counter, however, some modifications to the bistable multivibrator are required in order to get the division by 5 feature into the circuit. To best understand how this is done, consider the negative input pulses and the resulting waveforms on a time scale for all the tubes in the divide by 5 counter circuit as shown in figure 8-8.

Assume the A sections of the tubes in figure 8-8A, are conducting and the B sections are cut off. Under these conditions, notice the effect the negative input pulses have on the operation of the circuit. The first negative input pulse (t_1) causes all A sections to cut off and all B sections to conduct. Also notice that when V31B conducts, the rapid drop in plate voltage is fed through a differentiator circuit (not shown) and forms a negative spike at the grid of amplifier V30A. The output of V30B (an amplified negative spike) is immediately fed back to V33 and V32 and resets them to their original state.

Pulse t_2 reverses the state of all the tubes. Positive output pulses are shorted by the diode rectifier CR1 so no feedback occurs at t_2. Pulses t_3 through t_5 affect the state of the tubes as shown by the waveforms in figure 8-8A. At the end of pulse t_5, the circuit is in the same state as that prior to pulse t_1. Pulse t_6 duplicates the action of t_1, and another output pulse from V31B is produced. Once again feedback from V30B returns V32 and V33 to the condition they were in prior to pulse t_6. Four more pulses (t_7 through t_{10}) reset the circuit in preparation for the next series of pulses. Ten input pulses will produce two output pulses to produce the division by 5.

The feedback feature is the only difference between the divide by five counter and a normal chain of 3 multivibrators which would divide by 8.

DIVIDE BY 175 COUNTER

For each input of 175 pulses from the divide by 5 counter, there is an output of 1 pulse from the divide by 175 counter (fig. 8-8B). The counter uses eight bistable multivibrators and one feedback amplifier V17B. Operation of this counter is similar to that of the divide by 5 counter. Normally, a counter made up of 8 bistable multivibrators would give a count of 2^8 or 256. In this case, feedback from the output stage is applied via the feedback amplifier to multivibrators V29, V25, and V23 to introduce a count of 81 (1 count for V29, 16 counts for V25, and 64 counts for V23). Thus. the zero state for the divide by 175 counter is 81, and 175 input pulses will give 1 output pulse (81 plus 175 equals 256).

VERTICAL DRIVE

The output of the last multivibrator in the divide by 175 counter is differentiated and applied to the grid of V17B. The negative-going output of V17B (feedback pulse) is used to trigger V18A and V19 (fig. 8-5) at the field frequency (V18 is a bistable multivibrator and V19 is a one-shot multivibrator). The second pulse, required to trigger V18B, is derived from the divide by 5 counter. This second pulse is applied 2 1/2 horizontal lines after the first pulse, thereby producing a negative-going pulse 2 1/2 horizontal lines in duration at the output of V18B. The output of V18B is differentiated and then applied to cut off V17A. Only the trailing edge is amplified by V17A. The negative-going pulses at field frequency appearing in the plate circuit of V17A are applied to the grid of V16A.

A vertical drive generator V16 of the bistable multivibrator type is triggered by V17A to

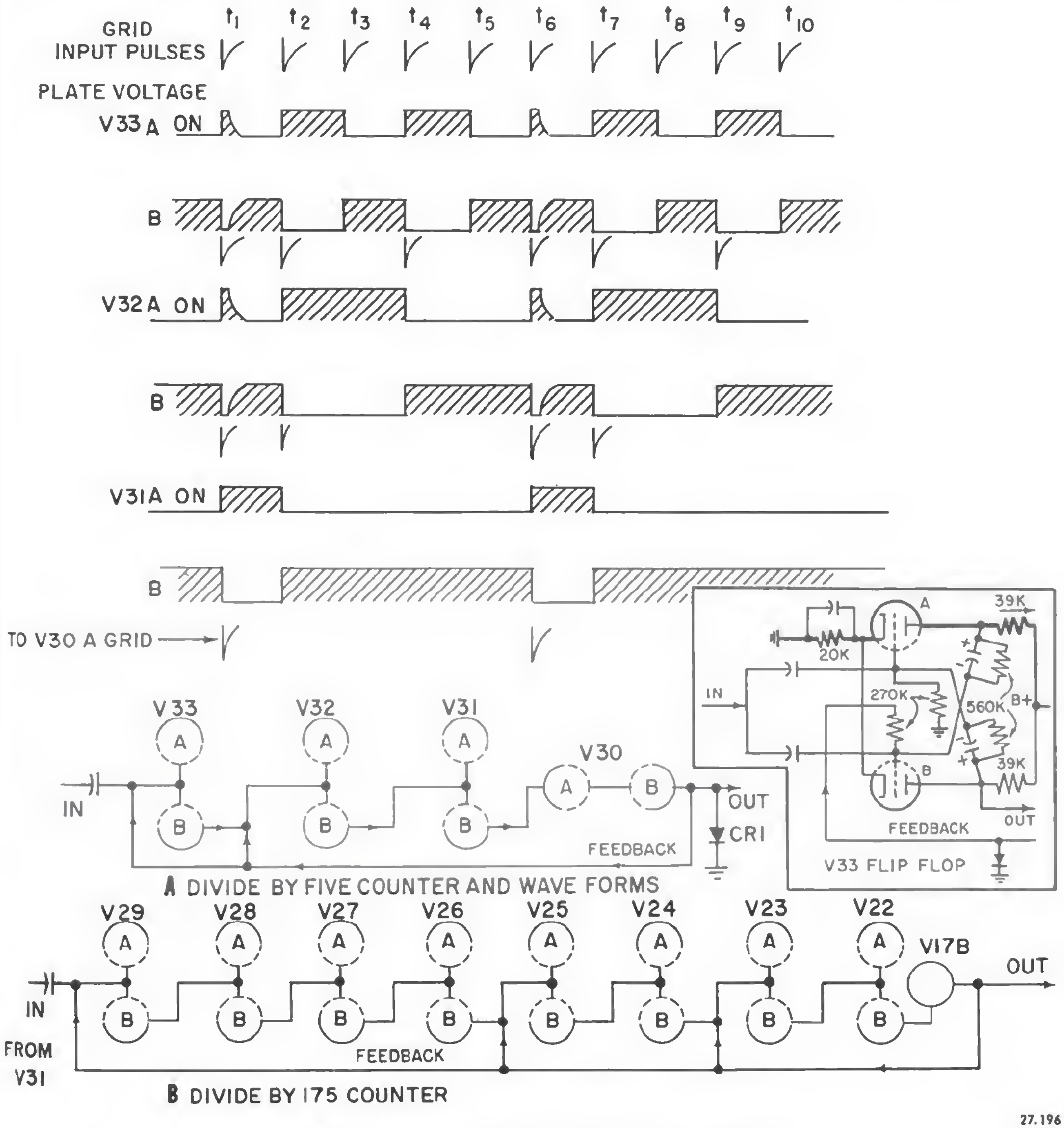


Figure 8-8.—Divide counters and waveforms.

produce the leading edge of the vertical drive pulse. The trailing edge is produced 15 horizontal lines later, when a negative-going pulse is applied to V16B from the divide by 175 counter. The output of V16A is a positive-going pulse 15 horizontal lines in duration, delayed 2 1/2 horizontal lines from the leading edge of the vertical blanking pulse, and is applied to the vertical drive clipper V15.

VERTICAL BLANKING

The vertical blanking pulse is produced by V19 (fig. 8-5). This one-shot multivibrator is

triggered by a pulse from feedback amplifier V17B at the field frequency. The duration of the negative-going pulse at the output of V19 is approximately 800 μs, or 21 horizontal lines.

The mixed blanking, horizontal drive, clipper, and output stages have been previously discussed and, with the exception of the power supply, this completes the discussion of the pulse generator section.

POWER SUPPLY

Operating voltages for the pulse generator are obtained from a separate power supply. The voltage regulated supply is conventional in most respects and a detailed explanation will not be given here.

A time delay is provided so that all tube heaters can reach operating temperature before B+ voltages are applied. An indicator lamp lights when voltage is applied to the primary of a power transformer. Another transformer supplies heater power to a delay relay circuit. When the delay relay operates, it completes the circuit to the main relay, which, when energized, couples the output of the rectifiers to the regulator.

An electronic voltage regulating circuit stabilizes the B+ voltage at 200 volts. A negative bias of 5.2 volts, applied to the output stages of the pulse-forming circuits, is developed at the rectifier end of a resistor connected between the negative side of the bridge rectifier power supply circuit and ground.

TRIGGER PULSE AMPLIFIER

The pulse generator (fig. 8-4) is isolated from the television viewer by the trigger pulse amplifier. The trigger pulse amplifier has a relatively high input impedance compared with the output impedance of the pulse generator and because of this fact, several trigger pulse amplifiers may be connected, in parallel, across an output of the pulse generator.

The trigger pulse amplifier (fig. 8-9) consists of three stages, including a dual output stage. The first stage, V1B, is a wide-band amplifier employing high-frequency compensation in the plate circuit. Cathode follower V1A furnishes a low impedance output for use in driving pulse amplifiers V2A and V2B, the inputs of which are connected in parallel. The outputs of V2A and V2B are applied, through coaxial transmission lines, to the television viewers or cameras.

Negative input pulses are applied to V1B. The screen grid of V1B is held at a relatively low potential by a voltage divider. The screen grid voltage determines the range between

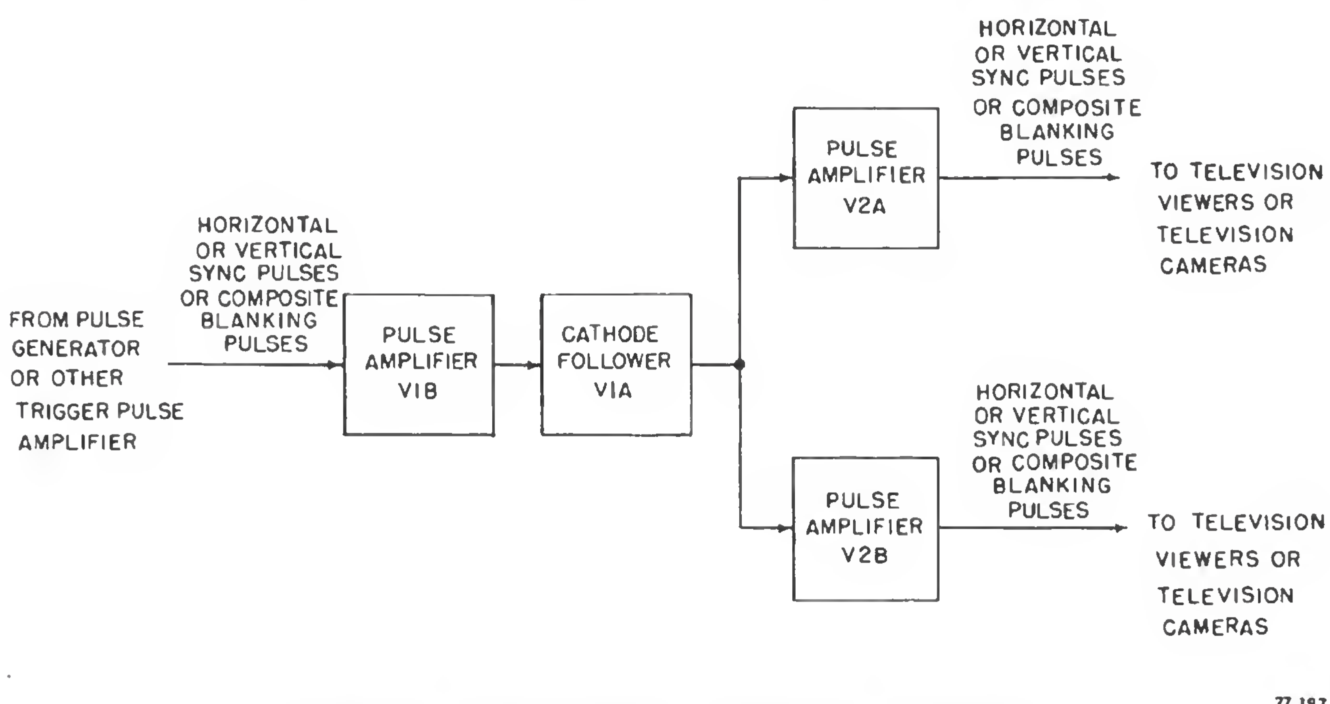


Figure 8-9.—Block diagram, trigger pulse amplifier.

cutoff and zero control grid voltage of V1B. Because this range is less than the amplitude of the input pulse, the negative portion beyond cutoff is clipped. The positive output pulses of V1B (180 degrees out of phase with the input pulses) are d-c coupled to the control grid of cathode follower V1A. The output of V1A provides a low impedance drive for the parallel connected grids of V2A and V2B. These two pulse amplifiers are fed with positive-going pulses which cause grid current to flow. The flow of grid current charges the V1A output coupling capacitor negative on the side next to the V2 grids.

During the interval between input pulses, the coupling capacitor discharges through the V2 grid resistor and the resulting grid leak bias drives V2 to cutoff. This action clips the baseline of the input pulse. By clipping the negative portion of the input pulse to V1B and the baseline of the input pulse to V2A and V2B, overshoots that may have been present in the input pulse to V1B are eliminated.

The output pulses of V2A and V2B are applied to coaxial transmission lines.

TELEVISION VIEWER

In appearance, the closed circuit television viewer is similar to a home television set. However, it has neither an audio system nor an r-f tuner.

The television viewer receives video and blanking signals from the camera and drive signals from the pulse generator through two interconnecting boxes. Figure 8-10 is the block diagram of the viewer.

The video and blanking signals are fed to the video amplifiers through a coaxial cable. After amplification, these signals are fed to the control grid of the 21-inch picture tube. Horizontal and vertical drive signals are received via separate coaxial lines and supplied to the horizontal and vertical sweep circuits respectively. The horizontal sweep circuit produces the electro-magnetic deflection of the electron beam in the horizontal direction. In addition, the horizontal sweep circuit provides a pulsed output for the high voltage (18-kv) supply. Thus, the high voltage supply is driven by the horizontal frequency (normally 26,250 cps). This feature provides protection for the picture tube against burning a spot in the mosaic should the horizontal sweep circuit fail.

The vertical sweep circuit supplies the electromagnetic deflection voltage for the picture tube and a signal for the focus modulator section. The focus modulator is required to prevent certain distortions in the reproduction of the CIC plotting board. Distortion is possible because the face of the picture tube is curved and the camera is focused on the flat CIC plotting board. There is also a loss of resolution in the corners of the display because of the length of the sweep.

To increase the resolution in the corners and compensate for the curvature in the face of the picture tube, a parabolic waveform (produced in the vertical sweep circuit) is applied to an electromagnetic focusing coil. The primary focus field is provided by a fixed permanent magnet assembly.

The relationship between the video, blanking, and drive signals is shown by the timing diagram, figure 8-11. The viewer operates at a field rate of 60 cps and the line rate is 26,250 cps with 875 lines per frame. Video and horizontal blanking pulses are received for 417 1/2 lines which constitutes the first field. Each horizontal drive signal, which starts retrace for each line, occurs during the horizontal blanking pulse.

At the end of field 1 (which ends on a half line), the vertical blanking signal which is part of the video signal is received to blank the display during vertical flyback. The vertical drive signal is delayed two lines from the leading edge of the blanking signal and is present for 15 horizontal lines; field 2 then starts in the middle of line 437 and ends in the middle of line 875.

VIDEO AMPLIFIERS

The combined video and blanking signals from the television camera control are amplified by four video amplifiers before they are applied to the control grid or picture tube V5 (fig. 8-10).

VERTICAL SWEEP CIRCUIT

Vertical drive signals from the trigger pulse amplifier are fed to the vertical sweep circuit (fig. 8-12) via J2. Switch S2 is closed only in the last viewer in the input line to connect R35 across the line to ground as an impedance match.

The negative drive signal is amplified by V6A and applied as a positive signal to the grid of V6B. Discharge tube V6B is normally held cut off between drive signals by the discharge of C20 through R36. When the positive drive signal

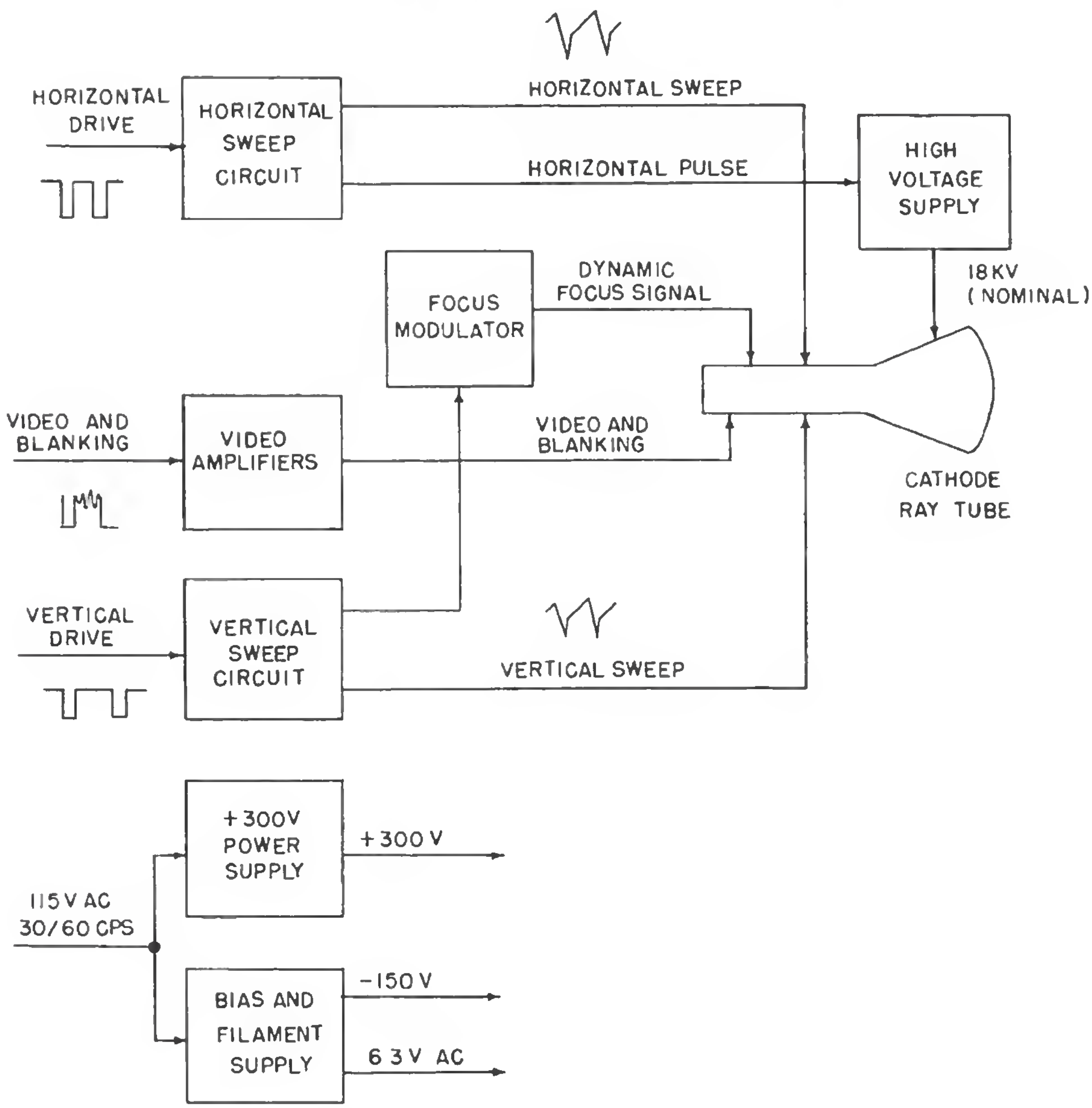


Figure 8-10.—Block diagram of viewer.

is applied to V6B the tube conducts drawing grid current and charging C20.

The output of V6B is a negative-going pulse which is applied to the grid of V7 through C24, R41, and R81. Resistor R81 is used as a parasitic suppressor and has no effect on the shape of the pulse. The normal output of V6B is a square wave, and a trapezoidal voltage wave is needed.

To obtain the desired waveform, a resistance-capacitance network (C22, C23, R42, and R39) is connected to produce degeneration between the plate and grid of V7. The degenerative network is energized by the alternate charging current through R37 and R38, and the discharge current through the plate circuit of V6B. Resistor R40 provides some overall linearity, and the vertical linearity control R39 adjusts the ratio of step to sawtooth components that are generated in the trapezoidal waveform.

The output at the plate of V7 is a trapezoidal waveform that is coupled through T1 to the vertical deflection coils. The current through these coils has a sawtooth wave shape and produces a linear sweep down the face of the picture tube. Resistors R79 and R80, connected across

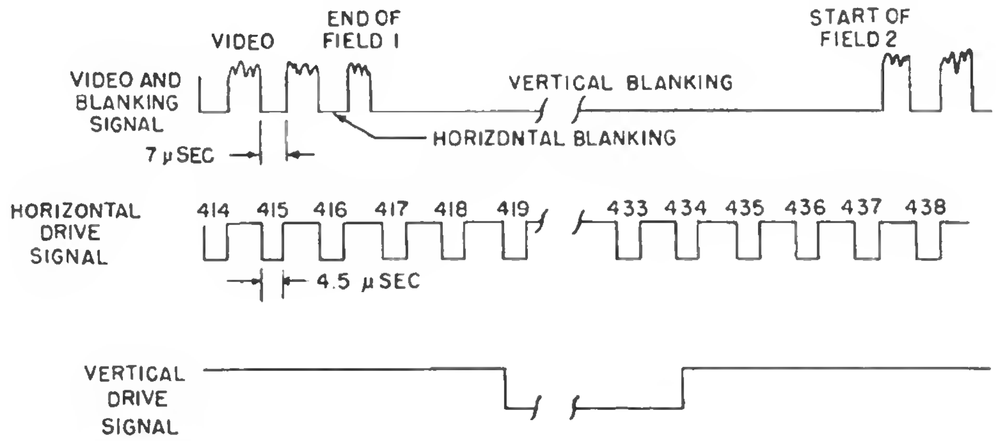


Figure 8-11.—Timing diagram. 27.199

the vertical deflection coils, reduce transient oscillations that are coupled from the horizontal deflection coils during horizontal retrace periods.

The linear sawtooth current developed in the plate circuit of V7 produces a parabolic voltage across C26. Part of this voltage, taken from the arm of R84, is fed to the focus modulator circuit and used to provide a varying magnetic focus field to compensate for the curvature of the face of the picture tube.

HORIZONTAL SWEEP CIRCUIT

Driving signals for the horizontal sweep circuit are received from the trigger pulse amplifier through J3 (fig. 8-13). Switches S3 and R45 are used for impedance matching as described previously for the vertical drive input. The negative drive signal is amplified and clipped by V8A and applied as a positive signal to the grid of V8B. During the no signal period, V8B is normally held cut off between drive signals by the discharge of C30 through R53. When a positive-going drive signal is applied to the grid of V8B, the tube conducts. During the conduction time, V8B draws grid current and charges C30. The action is similar to that previously described for the corresponding input tube in the vertical sweep circuit.

During the time when V8B is cut off, C32 attempts to charge to a voltage determined by the setting of the WIDTH control R54. However, before C32 becomes fully charged, the drive signal causes V8B to conduct and C32 to discharge through the tube. The conduction time of V8B is so short that C32 cannot discharge completely before the tube is again cut off. The plate voltage of V8B will then immediately rise to a potential determined by the setting of R54. The sudden voltage rise produces the step in the required trapezoidal waveform. Capacitor C32 then starts to charge to the value set by R54. Before the capacitor is fully charged, the next drive pulse is received and the capacitor discharges, starting the next cycle.

The trapezoidal voltage waveform is applied to the grid of the horizontal deflection amplifier, V9, driving the tube into conduction. During the linear rise in plate current, tube V9 conducts through the damping diode V16. At the start of the retrace (flyback), a large positive pulse of voltage is generated across the deflection coils, making the cathode of V16 positive with respect to its plate, and the diode cuts off. The deflection coil circuit begins to oscillate at its natural frequency when the output tube is cut off. Oscillation continues for approximately one-half cycle. After the half-cycle, the cathode is made negative and the diode begins to conduct again, damping the oscillations and producing a linear decay of current in the deflection coils. The linear decay is used to sweep the electron beam for approximately one-third of the horizontal trace. At this time V9 begins to conduct and produces the remaining two-thirds of the horizontal sweep.

The inductance of the horizontal linearity control L8 is made adjustable so that slight changes can be made in the plate supply voltage to vary the plate characteristics of V9. The variation of the plate characteristic is used to

compensate for the otherwise nonlinear rise of sawtooth current in the deflection coils.

Part of the signal developed across the secondary of T2 is sent to the high voltage supply. This signal is used to provide an input signal at the horizontal frequency for generating the high voltage needed for the picture tube.

FOCUS MODULATOR

The focus modulator, V10B and V17 (fig. 8-12), varies the current through a focus modulator coil (L9) to keep the electron beam converged at the face of the picture tube regardless of the deflection. Because this is a constantly varying focus arrangement, it is called dynamic focusing.

The waveform of the vertical signal received by the modulator is a parabola whose amplitude is controlled by the vertical parabola potentiometer (R84, fig. 8-12). The parabolic voltage is amplified by V10B and applied to the grid of V17 through C54 and R85. The output of V17 appears across L9 as a parabolic waveform. Coil L9 is mounted on the neck of the picture tube where it provides a varying magnetic field to alter the beam convergence in the desired manner.

HIGH VOLTAGE SUPPLY

The pulse-type high voltage power supply (fig. 8-13) is driven by signals from the horizontal sweep circuit. The output voltage, nominally 17,500 volts, is adjusted between the limits of 15,000 and 18,000 volts by the FOCUS control on the view panel.

The high voltage circuit receives a positive-going pulse from the horizontal output transformer T2 (fig. 8-13) for each horizontal sweep generated. Operation of the high voltage supply is similar to that of a high-efficiency horizontal deflection circuit.

A trapezoidal waveform is applied to the grid of a power amplifier tube in the high voltage power supply section. The output of the power amplifier is applied through a step-up high voltage transformer and two series-connected diode rectifiers to provide high d-c voltage for the picture tube.

Beam convergence in the picture tube is a function of high voltage as well as the focus magnet position and strength. Because the focus magnet strength is fixed, operational adjustment of focus is obtained by adjustment of the high voltage output.

300-VOLT POWER SUPPLY

Operating voltages (plate supply for the viewer) are furnished by a conventional power supply with bridge rectifiers, a choke input filter, and a series regulator to provide a +300 v d-c output.

Primary power (115 v a-c, 50-60 cycles) is applied to the primary of the filament transformer. A time delay relay which has its heater coil connected to one of the filament transformer secondaries closes its contacts after warmup and applies line voltage to the primary of the power transformer.

BIAS AND FILAMENT SUPPLY

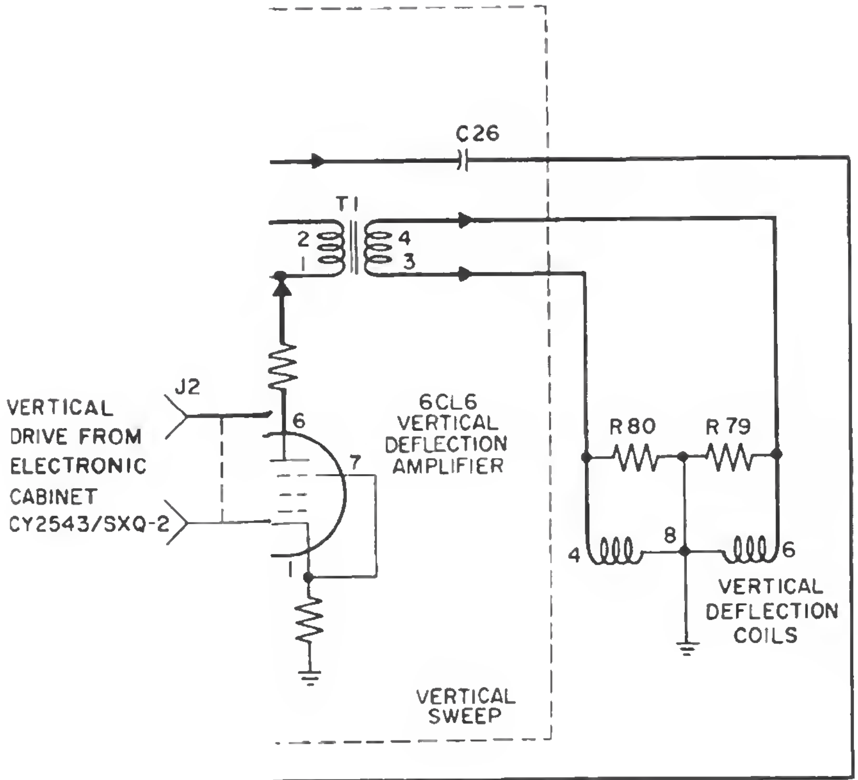
The bias and filament transformer has two secondaries, one of which furnishes 12 amperes at 6.3 volts to all filaments and the other furnishes 400 volts rms which is rectified, filtered. and regulated to supply -150 volts bias.

TELEVISION CAMERA

The television camera equipment consists of a television camera and its television camera control system. Figure 8-14 is an overall functional block diagram for the television camera and camera control equipment. This equipment converts the image viewed by the camera tube into a video output signal that is used to produce an identical image on the picture tube in the television viewer.

The functional block diagram for the vidicon camera tube section is shown in figure 8-15. The video signal is generated by the vidicon camera tube when an image is present at the face of the tube. The vidicon camera tube uses magnetic deflection for beam scanning and centering.

Beam scanning is produced by the application of sweep voltages to the horizontal and vertical deflection coils. Centering is obtained by varying the magnitude of a direct current that is being applied to the deflection coils. The camera tube is protected against damage due to the loss of either horizontal or vertical sweep voltage by the operation of the sweep loss protection stage. This stage detects the absence of sweep voltage; then removes the accelerator voltage from the camera tube. The tube is then held cut off until sweep voltages are restored.


C26
T1
2
1
4
3
J2
VERTICAL
DRIVE FROM
ELECTRONIC
CABINET
CY2543/SXQ-2
6
7
1
6CL6
VERTICAL
DEFLECTION
AMPLIFIER
R80
R79
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8
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COILS
VERTICAL
SWEEP

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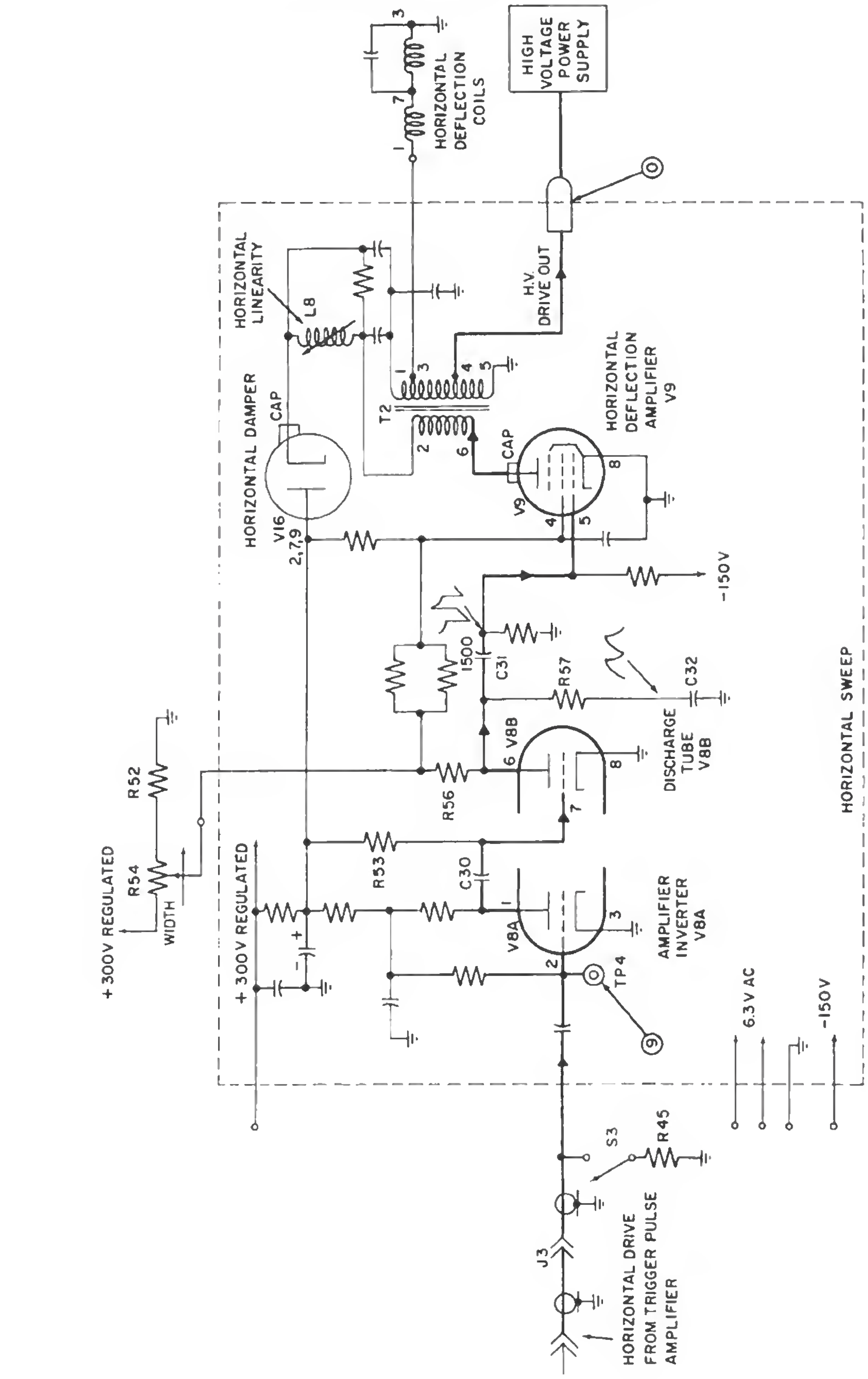

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Figure 8-13.—Television viewer horizontal sweep circuit, schematic diagram.

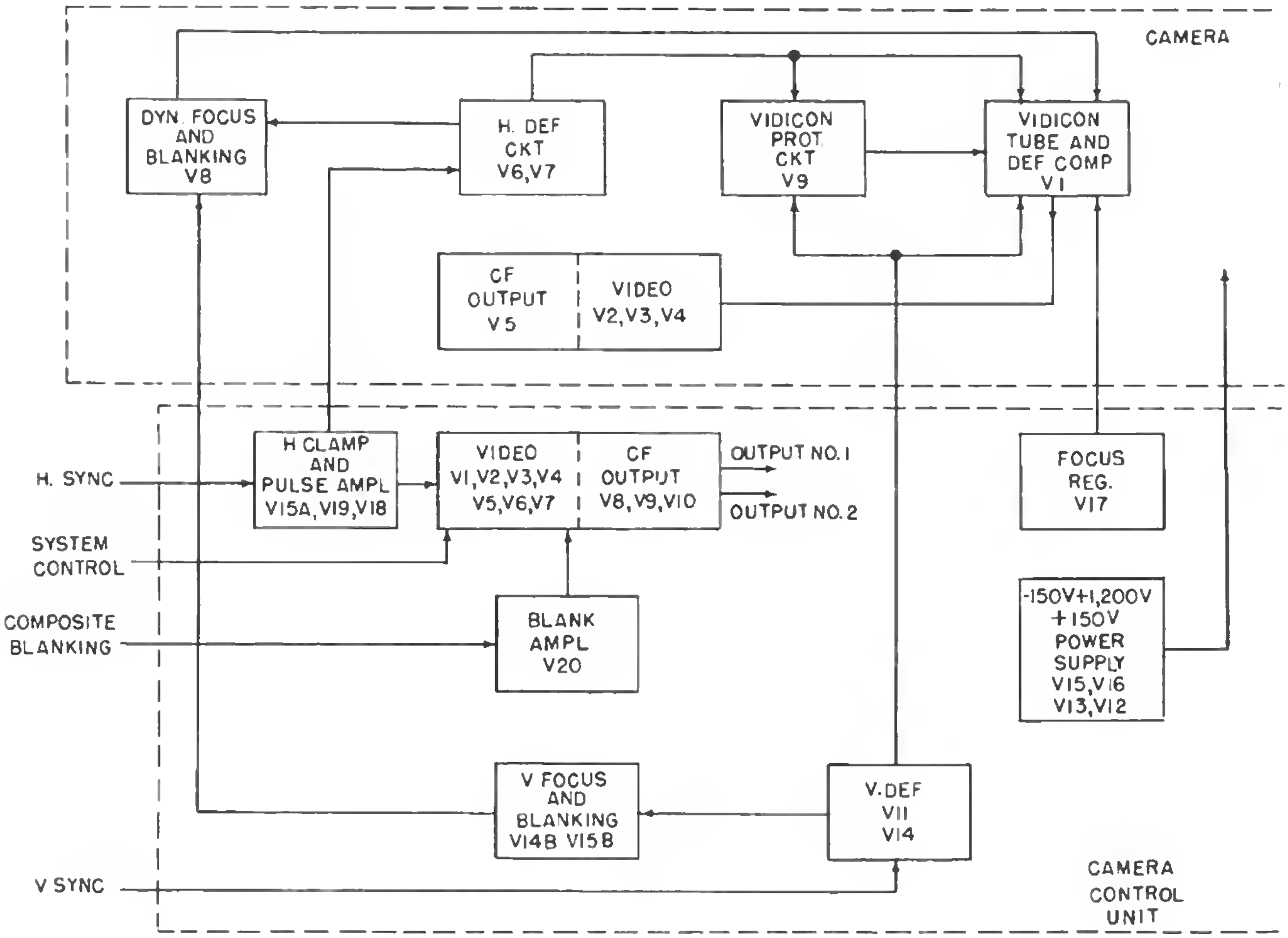

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Figure 8-14.—Television camera equipment functional block diagram.

The operating characteristics of the camera tube are controlled by beam control, target, and focusing anode voltages. In addition to these voltages, a camera blanking and dynamic focusing voltage is applied to the cathode of the camera tube. The blanking portion of the voltage applied to the cathode prevents video generation during the period of sweep retrace. The dynamic focusing portion of the signal compensates for poor focusing at the edges of the viewed image. This compensation is necessary because the vidicon tube screen is flat and the length of the electron-beam path varies during beam scanning. Dynamic focusing varies the initial velocity of the electrons leaving the cathode and provides uniform beam focusing across the vidicon screen, compensating for the difference in the path length of the beam at the center of the sweep as compared to either end.

VIDEO SECTION

The video section (fig. 8-16A) contains the video amplifiers, clamping circuits, and blanking amplifiers. The video amplifiers have a 20-megacycle bandpass, and the clamping circuits and blanking amplifiers are used to insert horizontal and vertical blanking pulses into the camera video signal.

The video signal from the vidicon tube is amplified and then fed to the camera control. In the camera control unit, the video is further amplified and then fed to V5A. In V5A, the camera video signal is divided into two paths. One path feeds the signal through capacitor C20 to the V6B grid (fig. 8-16B) and the other path is through an additional amplifier (V5B) to the V6A grid. Low-frequency components on the V6 grids are 180° out of phase and cancel in the

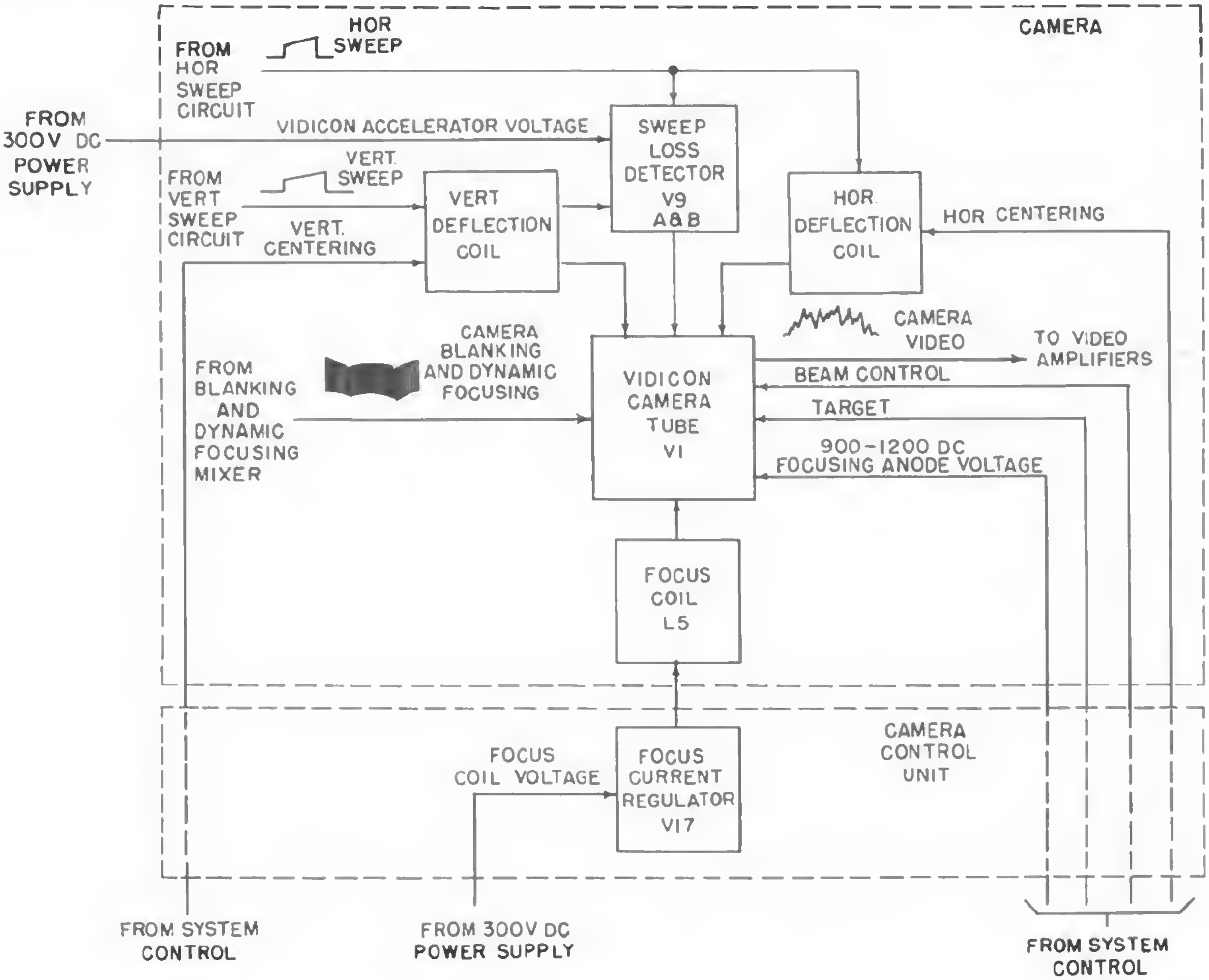

Figure 8-15.—Functional block diagram for vidicon camera tube section in the television camera.

output. High-frequency components are amplified in V5B and V6A to extend the high-frequency range.

This action reduces aperture distortion. Aperture distortion is the loss of picture resolution (detail) due to the width of the electron beam in the camera tube. Thus, increasing the high-frequency gain of the amplifiers improves the picture detail in the viewer.

The viewer blanking pulse from the clamp diode and the blanking pulse from the blanking amplifier are inserted at V7.

The input signal to the clamping circuits is a horizontal drive pulse from the pulse generator in the television system. This pulse is amplified by horizontal drive amplifier V15A and clamp pulse amplifiers V19. The output of V19 is applied to the horizontal sweep circuits in the camera, and to the clamp diode V18. Diode V18 establishes the d-c level of the video signal at the end of each horizontal interval, thus providing a reference level for blanking insertion. The mixed blanking (horizontal and vertical) is applied to the plate of V7. The pedestal voltage from the system control sets the magnitude of cut off voltage applied to V7 by V18.

After insertion of the view blanking signal from V20, the signal is fed through three more stages of video amplification, V8, V9, and V10.

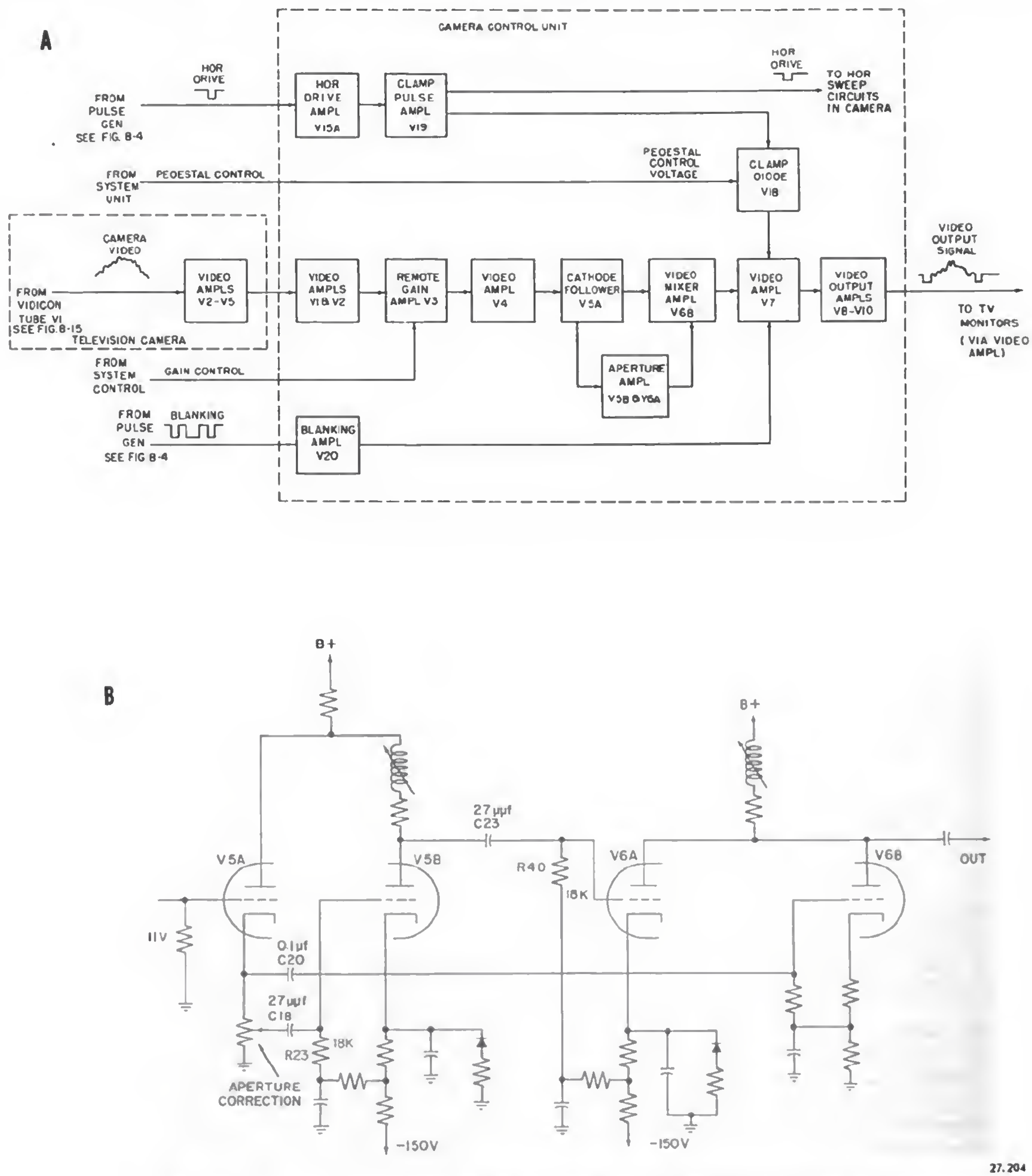

Figure 8-16.—A. Video section in camera control unit, block diagram.
B. Aperture correction schematic.

The output of V10 is distributed by video amplifiers (external to the camera equipment) to the appropriate television viewers.

The video circuits (fig. 8-16A) amplify the camera video signal, provide high frequency and aperature compensation, control video gain, and insert blanking pulses into the video signal.

The gain of V3 is determined by the d-c bias GAIN control in the television system control. The grids of both triode sections of V3 return to the d-c bias control so that any change in bias will change the operating point of both triodes.

Both shunt and series peaking are used to increase the high-frequency response in the video amplifiers.

SWEEP, BLANKING, AND DYNAMIC FOCUSING SECTION

The sweep, blanking, and dynamic focusing section (fig. 8-17) is composed of a horizontal and vertical sweep circuit, two blanking and dynamic focusing amplifiers, and a blanking and dynamic focusing mixer. This section is fed by both horizontal and vertical drive pulses from the pulse generator section.

The vertical drive pulse is amplified by a vertical pulse amplifier V11A in the camera control. The amplified output is applied to the blanking and dynamic focusing amplifier V14B and V15B, and the vertical sweep generator V11B. The blanking and dynamic focusing amplifier uses the vertical drive pulse for camera vertical blanking. When the vertical drive pulse is applied to the vertical sweep generator, a vertical deflection amplifier supplies sawtooth current to the vertical deflection coil. The output of the vertical deflection amplifier V14A is also integrated and forms a parabolic voltage. This parabolic voltage is used for vertical dynamic focusing and is mixed with the vertical camera blanking pulse at the blanking and dynamic-focusing amplifiers V14B and V15B. The output of V15B is applied to a blanking and dynamic focusing mixer V8B in the camera. The mixer also receives a horizontal blanking and dynamic focusing signal. The horizontal and vertical blanking and the dynamic focusing signals are mixed in V8B and applied to the vidicon tube.

CAMERA TUBE CIRCUITS

A video signal is generated when an image appears on the photosensitive surface of V1 (fig. 8-14). To obtain the photosensitive surface, the face plate of the vidicon tube has its inside surface coated with transparent electrical conducting film called the target or signal electrode. When the individual elements making up the photosensitive layer are exposed to light through the optical window (lens) of the camera, each element charges to a d-c potential that is proportional to the amount of incoming light. The signal electrode is scanned by a moving electron beam, and as this beam strikes the charged elements they are discharged through a load resistor. The voltage across the resistor represents the camera video signal which is applied to a video amplifier V2.

Deflection of the electron beam is accomplished by transverse magnetic fields produced by horizontal and vertical deflection coils. The current through focus coil L5 (fig. 8-15) is regulated by V17 in the camera control unit. The bias of V17 is adjustable, thus controlling the current through the series-connected V17 and the focus coil.

Focusing of the electron beam is accomplished by a transverse magnetic field that is produced by two circular permanent magnets located at the base end of the focus coil. These magnets can be rotated by hand to produce the proper beam alignment.

Sweep loss protection is provided by a relay, and cascode amplifiers V9A and B (fig. 8-15). The absence of either sweep voltage (or both) will cause the plate current of the amplifier to decrease and deenergize the relay which opens its contacts and removes the accelerator voltage from V1. This action cuts off V1 until normal sweep voltages are restored.

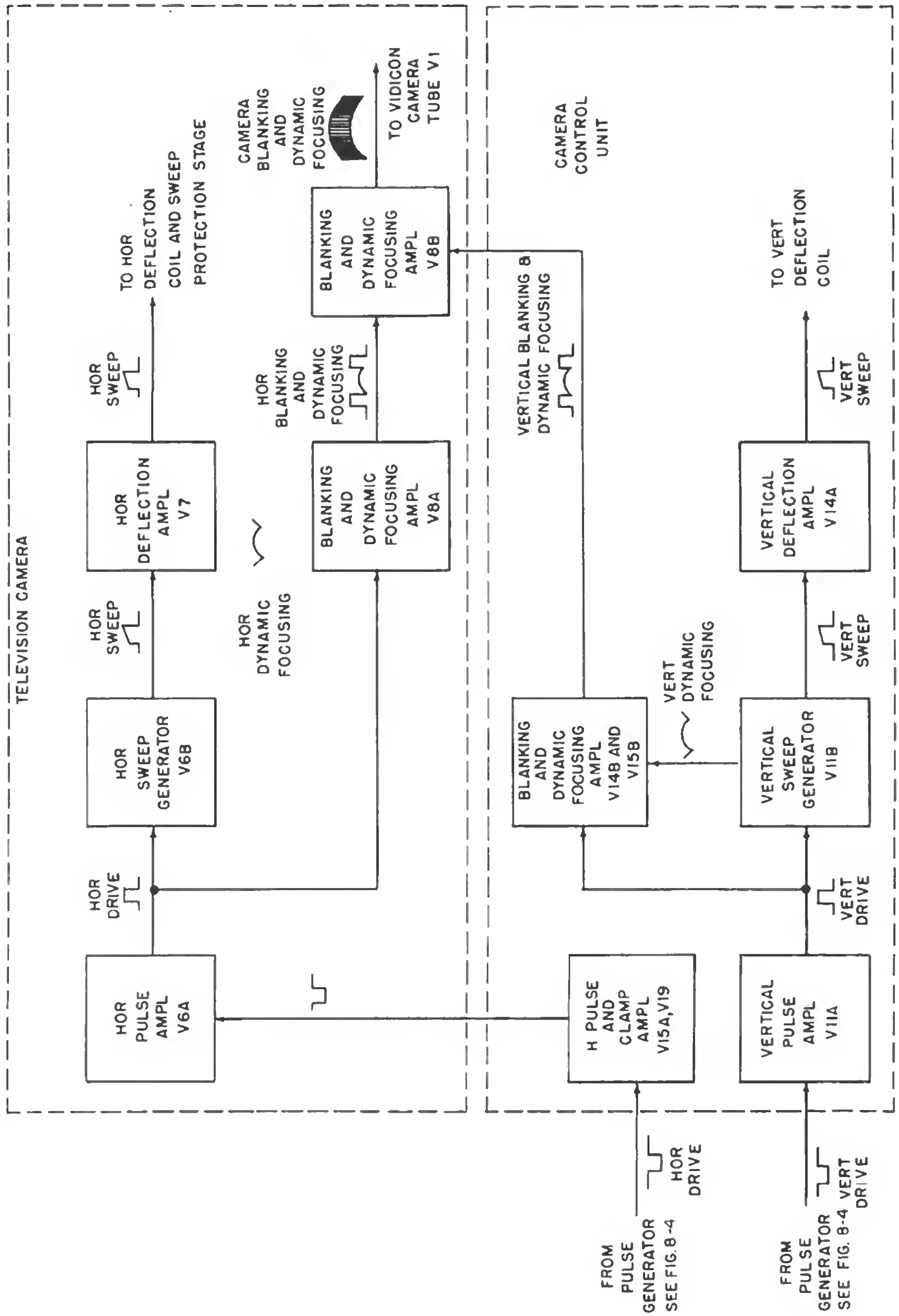

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Figure 8-17.—Sweep, blanking, and dynamic focusing section, block diagram.

CHAPTER 9

SAFETY PRECAUTIONS

Responsibility for the safety of personnel is vested in the commanding officer. Article 0712 of U. S. Navy Regulations reads as follows: "The Commanding Officer shall require that all persons concerned are instructed and drilled in applicable safety precautions and procedures; that they are complied with and that applicable safety precautions or extracts therefrom are posted in appropriate places. In any instance where safety precautions have not been issued or are incomplete he shall issue or augment such safety precautions as he deems necessary, notifying when appropriate, higher authorities concerned."

While the commanding officer cannot delegate his responsibility for the safety of all personnel under his jurisdiction he must necessarily delegate his authority to all officers and petty officers under his command to ensure that all prescribed safety precautions are understood and enforced according to the above article.

As the leading I.C. Electrician your responsibilities regarding safety may be grouped into three areas as follows:

1. Responsibilities concerning the I.C. group or E division—these responsibilities include ensuring that all men in the group are aware of and are observing all shipboard safety precautions, especially those regarding electrical safety.

2. Responsibilities concerning non-electrical ratings—as an IC1 or Chief I. C. Electrician you will automatically be considered an expert on electrical safety precautions. Thus you have a responsibility to educate the men, whose primary duties are non-electrical, in these precautions. The responsibilities in this area are ever increasing as more and more electrical machines and equipment are being utilized for the various jobs aboard ship.

3. Responsibilities as a petty officer—in this area you have the same responsibilities as all other petty officers of equal rates in enforcing all safety precautions.

ELECTRIC SHOCK

From 1946 through 1961, 82 men died as a result of electric shocks received aboard U. S. Navy ships (fig. 9-1). Table 1 summarizes each death from 1957 through 1960 as to rate, type of ship, voltage, and equipment involved.

Current flow through the body is the cause of electric shock. Factors determining the extent of the body damage due to electric shock are the amount and duration of the current flow, the parts of the body involved, and the frequency of the current if a-c. In general, the greater the current or the longer the current

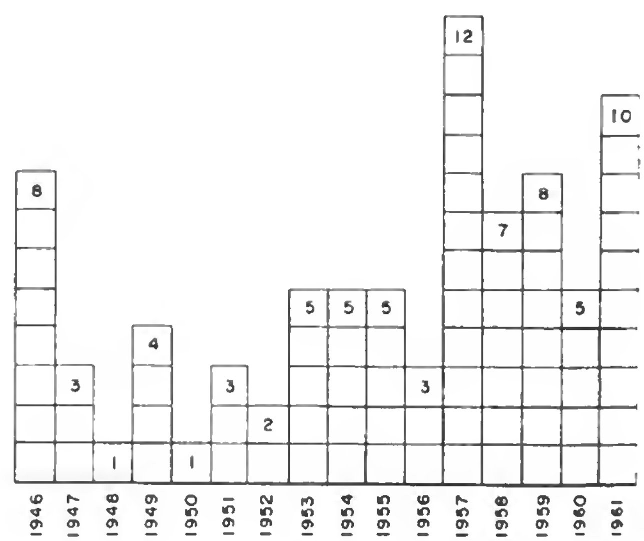

Figure 9-1.—Deaths caused by electric shock on U. S. Navy ships.

Table 9-1.—Summary of Shipboard Deaths Due to Electric Shock—1957 through 1960.

Death No.	Rate	Type Ship	Voltage	Equipment
1957				
1	FTC	DE	800 a-c	Radar
2	BT3	EDE	120 a-c	Portable light
3	SN	DE	120 a-c	Portable grinder
4	FN	CVA	120 a-c	Portable light
5	FT1	DUR	800 a-c	Radar
6	EMC	DDE	440 a-c	Motor (vent set)
7	SA	AO	120 a-c	Portable wire brush
8	SN	CVS	440 a-c	Portable welder
9	SN	AR	120 a-c	Fan
10	TM_3	AB	120 a-c	Gooseneck lamp
11	BTEA	CVS	120 a-c	Portable light
12	EM_3	AKA	230 d-c	Power panel
1958				
1	PA	DDR	440 a-c	Controller panel
2	FN	DD	120 a-c	Portable light
3	EM_1	SSK	120 d-c	Light in generator
4	MM_3	DD	120 a-c	Electric drill
5	EM3	LST	446 a-c	Main switchboard
6	EM_3	ARS	120 d-c	Electric drill
7	FN	DD	120 a-c	Lighting fixture
1959				
1	SCG_3	DDE	8000 a-c	Sonar transmitter
2	SOSN	DDE	8000 a-c	Sonar transmitter
3	AN	CVA	120 a-c	Portable wire brush
4	ET_3	CVA	2000 d-c	Radio transmitter
5	EM_3	CVA	440 a-c	Controller cover
6	FA	CVS	440 a-c	Open electrical box
7	RM_3	SS	120 a-c	Radio cabinet
8	SFM_3	DD	50 d-c	Welding electrode
1960				
1	MM_3	DDE	120 a-c	Electric drill
2	ETR SN	AGC	9600 d-c	Radar
3	ICFN	APA	120 a-c	I.C. test panel
4	SF_3	DD	50 d-c	Welding electrode
5	EMFN	DDR	440 a-c	Controller panel

flows, the greater will be the body damage. Body damage is also greatest when the current flow is through or near nerve centers and vital organs. Sixty-cycle current is considered slightly more dangerous than current of a lower frequency or d-c. This difference is small, however, and the same precautions that apply to 60-cycle a-c also apply to d-c.

Men differ in their resistance to electric shock, and consequently a current flow that may cause only a painful shock to one man might be fatal to another. Table 9-2 presents information from authoritative sources on the effects of 60-

cycle currents flowing through the body from hand to hand or hand to foot. U. S. Navy Safety Precautions (OPNAV 34P1) summarizes the effects of 60-cycle currents with 3 brief statements as follows:

1. At about 1 ma (.001 ampere) shock is perceptible.
2. At about 10 ma (.010 ampere) shock is sufficient to prevent voluntary control of the muscles.
3. At about 100 ma (.1 ampere) shock is fatal if it lasts for 1 second or more.

Table 9-2.—Sixty-cycle current values affecting human beings

Current Value	Effects
Less than 1 ma	No sensation.
1 to 20 ma	Mild sensation to painful shock, may lose control of adjacent muscles between 10 and 20 ma.
20 to 50 ma	Painful shock, severe muscular contractions, breathing difficult.
50 to 200 ma	Same as above, only more severe, up to 100 ma. A heart condition known as ventricular fibrillation may occur anywhere between 100 and 200 ma causing death almost immediately.
over 200 ma	Severe burns and muscular contractions so severe that the chest muscles clamp the heart and stop it for the duration of the shock.

High frequency currents ranging from about 200 kc and above have a tendency to flow along the surface of the skin (skin effect) and persons coming into contact with these currents usually suffer severe burns although the current may not penetrate the body.

PREVENTING ELECTRIC SHOCK

Two conditions must be present for an electric current to flow through the body and cause electric shock.

1. The body or some part of the body must form part of a closed circuit.
2. Somewhere in the closed circuit there must be a voltage, or a difference in potential, to cause a current flow. It follows then, to prevent electric shock you should, if possible, ensure that your body never forms part of a closed circuit.

Tests made by the National Bureau of Standards show that the resistence of the human body may be as low as 300 ohms under unfavorable conditions such as those caused by salt water and perspiration. This indicates immediately that it is possible for a potential difference as low as 30 volts to cause the fatal .1 ampere current flow through the body. It is true that this would be an extremely unfavorable condition; however, it leaves no doubt as to the dangers involved and precautions necessary regarding the 120-volt circuits aboard ship.

Practically all electric shocks are due to human failure, rather than equipment failure. Equipment may suddenly fail and cause fatal shock even if skillfully designed for safety, thoroughly tested before use, and used in accordance with applicable safety precautions. This can happen, but rarely does. Nearly all of the shipboard deaths reported in figure 9-1 were caused by human failure manifested in one or more of the following ways:

1. Unauthorized use of, or unauthorized modifications to equipment.
2. Failure to observe the applicable safety precautions when using equipment or when working on or near energized equipment.
3. Failure to repair equipment which was known to be defective and had previously given a mild shock to users.
4. Failure to test and inspect equipment for defects or failure to remedy all defects found by tests and inspections. All of these failures may be summarized as failure to observe applicable safety precautions.

SAFETY PRECAUTIONS RELATING TO PORTABLE ELECTRICAL EQUIPMENT

Navy specifications for all portable electrical equipment such as drills, grinders, wire brushes, sanders, buffers, etc., require the electric cord for the tool to be provided with a distinctively marked grounding conductor in addition to the conductors supplying power to the

tool. Past practice was to use red for the grounding conductor in 3-conductor cords and green in 4-conductor cords. Revised specifications require that green be used for the grounding conductor in all cords for portable electrical equipment. BuShips has standardized on the use of grounded type plugs and receptacles to be installed on all ships. The use of a grounding conductor separate from the power cord and grounding to the ship with alligator clamps or other means are considered unsatisfactory.

All portable electrical equipment before being used for the first time must be tested, and periodic tests and inspections made thereafter on the equipment and installed receptacles according to Bureau of Ships Technical Manual, chapter 60.

Personal portable electrical equipment such as radios, record players, TV sets, coffee pots, etc., must be tested to ensure they meet Navy specifications before being allowed on board ship. If they do meet specifications and are authorized on board they require the same periodic tests and inspections as other portable electrical equipment.

SAFETY PRECAUTIONS IN SWITCHING AND SERVICING SWITCHBOARDS

Switches should be operated with both the safety of the operator and other personnel in mind. Before closing any switch be sure the circuit is ready in all respects to be energized and any men working on the circuit are notified that it is to be energized.

When operating circuit breakers or switches use only one hand if possible. Use judgment in replacing blown fuses. Only fuses of 10 ampere capacity or less should be removed or replaced in energized circuits. Fuses larger than 10 ampere ratings should be removed or replaced only when the circuit is deenergized. Work should not be done on any energized circuit, switchboard, or other piece of electrical equipment unless absolutely necessary. Circuits or equipment to be worked on should be deenergized by opening all switches through which power could be supplied and the circuit then tested with a voltmeter or voltage tester. These switches should then be tagged with warning tags. In case more than one party is engaged in repair work on a circuit a warning tag for each party should be placed on the supply switches.

When checking to see whether circuits are deenergized before starting repair work on switchboards be sure to check metering and control circuits.

Some instrument transformers will be energized even though main circuit breakers are open.

When military considerations require that electrical repair work be done on energized switchboards permission to do the work must be obtained from the commanding officer. The work should be done only by adequately supervised personnel fully cognizant of the dangers involved, and the following precautions observed.

1. Provide ample illumination.
2. The person doing the work should not wear wristwatch, rings, watch chain, metal articles, or loose clothing which might make accidental contact with live parts or which might accidentally catch and throw some part of his body into contact with live parts. Clothing and shoes should be as dry as possible.
3. Insulate the worker from ground by means of insulating material covering any adjacent grounded metal with which he might come in contact. Suitable insulating materials are dry wood, rubber mats, dry canvas, dry phenolic material, or even heavy dry paper in several thicknesses. Be sure that any such insulating material is dry, has no holes in it, and no conducting materials embedded in it. Cover sufficient areas so that adequate latitude is permitted for movement by the worker in doing the work.
4. Cover working metal tools with insulating rubber tape (not friction tape) as far as practicable.
5. Insofar as practicable, provide insulating barriers between the work and any live metal parts immediately adjacent to the work to be done.
6. Use only one hand in accomplishing the work, if practicable.
7. A rubber glove should be worn on the hand not used for handling the insulated tools. If the work being done permits, rubber gloves should be worn on both hands.
8. Station men by circuit breakers or switches, and man a telephone if necessary, so that the circuit or switchboard can be deenergized immediately in case of emergency.
9. A man qualified in first aid for electric shock should be immediately available while the work is being done.

These precautions apply to repair work on all energized circuits or equipment where the voltage exceeds 30 volts.

SAFETY PRECAUTIONS WHEN RIGGING CASUALTY POWER

There are definite procedures that must be followed and safety precautions that must be observed in rigging casualty power. Only qualified personnel should do the actual connecting; however, the portable cables may be laid out by other personnel. Safety precautions require the man making the connections to wear rubber gloves, and to stand on a rubber mat or wear rubber boots while making connections. He is further required to test each casualty power riser or bulkhead terminal with a voltage tester before making a connection. The portable cable connections for casualty power should always be made by first connecting at the load, then working back to the source of power. In making casualty power connections at a load where there are no circuit breakers or transfer switches to interrupt the incoming feeder cable, it must be disconnected or cut at the equipment. It is quite possible that this cable may be damaged by the casualty which caused the loss of power, and such a damaged cable if energized would probably trip the casualty power circuit breakers. If not disconnected, this incoming feeder cable may be reenergized and present a hazard to personnel handling the casualty power cables. Care should be exercised, in making all connections, to keep the phase sequence correct in a-c systems. If the load includes motors in either a-c or d-c systems, the connections should be made so as to include the motor controller in the circuit.

Casualty power cables should be tied to the overhead and high voltage signs should be attached at each connection. Also, it is common practice to pass the word over the ship's 1MC system, informing all hands to stand clear of the casualty power cables after they are energized.

Unrigging casualty power is also hazardous if not handled correctly. The recommended procedure is for the Electrician's Mate on the switchboard at the source of the casualty power supply to open the 225 or 250 ampere AQB circuit breaker behind the switchboard that supplies the system, and to remove both ends of the first cable nearest the source. After this has been done, both ends of the last cable in the system that connects to the load are disconnected and removed. The normal feeder or feeders may now be reenergized to the equipment, and the remainder of the casualty power cables are unrigged and restowed on the proper racks.

SAFETY PRECAUTIONS WHEN USING PORTABLE TEST EQUIPMENT

The electrical measuring instruments included in portable test equipment are of delicate construction, therefore certain precautions are necessary to avoid damage to the instruments and to ensure accurate readings. In addition there are other precautions that must be observed while using portable test equipment to avoid injury to personnel.

Three precautions that apply to all electric measuring instruments to avoid damage are:

1. Avoid mechanical shock—although the moving elements in electrical measuring instruments are light in weight the bearing pressure at pivots and jewel bearings often exceeds 10 tons per square inch because of the small area of the bearing surface.
2. Avoid exposure to strong magnetic fields—strong magnetic fields may permanently impair the accuracy of an instrument by leaving permanent magnetic effects in the magnet of permanent magnet moving coil instruments, in the iron instruments, or in the magnetic materials used to shield instruments.
3. Avoid excessive current flow--this includes various precautions depending on the type of instrument. Make connections while the circuit is deenergized if possible, and then check all connections to ensure that no instrument is overloaded before energizing.

Precautions to be observed to avoid instrument damage include the following:

1. Keep in mind that the coils of wattmeters, frequency meters, and power factor meters may be carrying excessive current even when the meter pointer is on scale.
2. Secondaries of current transformers should never be open circuited when the primary is energized.
3. Secondaries of potential transformers should never be short circuited when the primary is energized.
4. Ensure that meters in motor circuits can handle the motor starting current which may be as high as 7 or 8 times normal running current.
5. Never leave an instrument connected with its pointer off scale or deflected in the wrong direction.

6. Never attempt to measure the internal resistance of a meter movement with an ohmmeter as the movement may be damaged by the current required to operate the ohmmeter.

7. Never advance the intensity control of an oscilloscope to a position which causes an excessively bright spot on the screen or permit a sharply focused spot to remain stationary for any length of time.

8. In checking electron tubes with a tube tester provided with a separate "short test" always make this test first. If the tube is shorted, no further tests should be made.

9. Before measuring resistance always discharge any capacitors in the circuit to be tested.

10. Always disconnect voltmeters from field circuits or other highly inductive circuits before the circuit is opened.

Situations can arise very easily during the use of portable test equipment that are extremely dangerous to personnel. For example, you may have an oscilloscope plugged into one receptacle, an electronic volt-ohm meter plugged into another, a soldering iron in still another using an extension cord, or many other combinations.

Some of the hazards presented by situations such as these are coming into contact with live terminals or test leads, instruments being accidentally thrown to the deck due to a sudden roll of the ship; and personnel becoming entangled with the leads or cords. In addition, the situation may be such that a potential difference sufficient to cause severe shock may exist between the metal cases of the instruments.

Wires attached to portable test equipment should extend from the back of the instruments away from the observer if possible. If this is not possible, they should be clamped to the bench or table near the instruments. When using instruments at places where vibration is present the instruments should be placed on pads of folded cloth, felt, or similar material. Additional precautions are necessary when using portable test equipment during heavy seas.

Precautions to be observed to avoid injury to personnel include the following:

1. Ensure that the metal cases of all instruments are grounded.

2. Ensure that one side of the secondary of all external instrument transformers are also grounded.

3. If equipment must be energized for testing after removal from its normal rack or mounting, ensure that all parts normally at ground potential are securely grounded.

4. Avoid testing voltages in excess of 300 volts when holding test probes in the bare hands. Use rubber gloves or attach test leads after the equipment has been deenergized, then energize the equipment and read the meter. Ensure that any high voltage capacitors in the circuit and the terminals to be tested are discharged before attaching or disconnecting the test leads.

5. When feasible check for continuity and resistance rather than directly checking voltages.

6. Keep all unauthorized personnel clear of the area where portable test equipment is being used.

SAFETY PRECAUTIONS WHEN HANDLING ELECTRON TUBES

The use of larger cathode-ray tubes has increased the danger of implosion, flying glass, and injury from high voltage. The danger is greatly reduced if the tubes are properly handled. If they are handled carelessly, struck, scratched, or dropped, they can very well become an instrument of severe injury or death. The following precautions should be taken: (1) Goggles should be worn to protect the eyes from flying glass particles, (2) suitable gloves should be worn, and (3) no part of the body should be directly exposed to possible glass splinters caused by implosion of the tube. (The coating on some tubes is poisonous if absorbed into the blood stream.)

Cathode-ray tubes must not be unnecessarily exposed to possible damage. When a tube is being unpacked, remove it from the packing box with caution, taking care not to strike or scratch the envelope. Insert it into the equipment socket cautiously, using only moderate pressure. When the tube must be set down, it is important that it be placed on a clean, soft padding. If special tube-handling equipment is available, it should be used according to instructions.

Electron tubes containing radioactive material are to be handled and disposed of in accordance with Electronic Supply Office Instruction 5100.1.

Poisoning from radioactive materials in the subject electron tubes may be of three types.

1. ASSIMILATION—Eating, drinking, or breathing radium or radium compounds or absorbing them through cuts. Radium-bearing dust, which may be present in certain tubes, is dangerous in this respect.
2. BREATHING RADON—Radon is a tasteless, ordorless, colorless gas that is given off by radium and radium compounds at all times. When breathed into the lungs it may cause severe injury.
3. RADIATION—Radium and radium compounds give off harmful, invisible radiations that can cause dangerous burns.

Radium bromide is used in spark-gap, glow-lamp, and cold cathode tubes. Radioactive cobalt is used in TR tubes.

Glow lamps, cold cathode tubes, and TR tubes contain from 0.01 to 1.0 micrograms of equivalent radium per tube. Spark gap tubes contain from 1.0 to 2.0 micrograms of equivalent radium per tube.

Radium bromide causes the formation of randon gas within the tube envelope, and it is dangerous to inhale this gas. Radium salts are cumulative poisons and, like other radioactive concentrations, are extremely hazardous if injected anywhere into the human system.

SAFETY PRECAUTIONS WHEN USING SOLVENTS AND VOLATILE LIQUIDS

Some solvents are flammable, others are toxic, and still others are both flammable and toxic. Alcohol must not be used on energized equipment or near any energized equipment from which a spark may be received. Gasoline or benzine should not be used for cleaning purposes under any circumstances. Carbon tetrachloride is not to be used because of it's extremely high toxicity. Inhibited methyl chloraform FSN-G6810-664-0388 or trichloroethylene FSN-G6810-184-4794 are approved cleaning solvents for applications in which carbon tetrachloride was previously used. Although these solvents are less toxic than carbon tetrachloride, they do present hazards to personnel, hence the following precautions must be observed when they are used.

1. Use with adequate ventilation.
2. Avoid prolonged breathing of the vapor.
3. Avoid prolonged or repeated contact with the skin.
4. Do not take internally.

These same precautions also apply when working with volatile liquids such as insulating varnish, lacquer, turpentine, and paints.

Solvent, dry cleaning, type 2 FSN-W6850-274-5421 is also an approved solvent in which the fire and health hazards have been minimized. Precautions against fire and explosion should still be observed, however, when using this solvent.

SAFETY REQUIREMENTS IN WORK AREAS

Safety requirements concerning the various shops and work areas aboard ship are prescribed by U. S. Navy Safety Precautions, BuShips Technical Manual, and other authority. The requirements for electrical or electronic working areas include the following:

1. Rubber matting meeting Military Specifications MIL-M-15562 is to be provided in the front and rear of all power and lighting, action cut out, I.C. and F.C. switchboards. This matting is also required in front of shipboard announcing system amplifiers and control racks, on areas around electronics equipment which may be contacted by personnel in servicing or tuning, and on areas in front of test benches or tables in electrical and electronic shops. Latest instructions require such matting to be cemented to the deck except on gratings and removable deck plates.
2. "Danger-high Voltage" signs and suitable guards are to be provided to warn all personnel, wherever live circuits or equipment are exposed when the voltage exceeds 30 volts.
3. All rear service switchboards are required to have an expanded metal enclosure with a door. This enclosure is not to be used as a storage space and the door must remain locked.
4. First aid treatment for electric shock and other applicable electrical safety precautions are to be posted in all areas containing major units of electrical or electronic equipments.
5. "No Smoking" signs are to be posted in spaces where storage batteries are charged, and all other spaces where explosive vapors may be present.

SAFETY DUTIES AND RESPONSIBILITIES

Your responsibilities concerning safety lie in three areas as mentioned previously. The duties

required to meet these responsibilities will include safety education, safety promotion, and safety enforcing duties.

SAFETY EDUCATION

You cannot expect a man to observe a precaution if he is unaware of the precaution. Your first duties therefore will be to ensure that all men in the I.C. group are aware of the safety precautions applicable to your ship. Ships such as AO's and AE's necessarily have some precautions that may not apply to other type ships. Ensure that all men have read and understand all posted safety precautions relating to the ship's electrical equipment.

Safety education for the non-electrical ratings should include information concerning electric shock and precautions they must observe when using electrical equipment aboard ship.

Facts to be brought out and points to stress to the non-electrical ratings concerning electric shock should include the following:

1. Voltages as low as 30 volts can be dangerous.
2. The dangers from electric shock are much greater aboard ship than ashore as the ship can be considered a floating bathtub.
3. There is very little middle ground between a slight tingle and a fatal shock.

Precautions they must observe when using electrical equipment include the following:

1. Always visually inspect portable electrical equipment before using. Look for damaged plugs, frayed cords, etc.
2. Never use portable electrical equipment if it is believed to be defective. Have it tested by authorized personnel.
3. Make no repairs.
4. Do not use any personal portable electrical equipment aboard ship unless it has been inspected and approved.
5. Always report any shock received from electrical equipment, regardless of how slight.

PROMOTING SAFETY

Promoting safety within the I.C. group, E division, or the ship in general will require you to become safety conscious to the point that you automatically consider safety in every job or operation. By safety reminders and your personal example you pass this safety consciousness on to the other men.

All men, even the "old hands" need to be reminded occasionally to work safely. The senior electrical rates involved in the fatal accidents (table 1) bear out this fact.

Promoting safety within the I.C. group can be done by various methods. Posters of the type shown in figure 9-2 can be helpful as safety reminders and in promoting safety. These posters are furnished periodically to all ships. Post them in your work areas and change them when new ones are available.

Periodic safety patrols or inspections made by the junior men in the group can also be helpful in promoting safety within the group and in reducing electrical hazards such as storage of foreign articles in or near switchboards, control appliances and panels, open panels or covers missing from junction boxes, etc.

In addition, occasional short group discussions concerning electrical safety is recommended. These discussions may take place at any time without prior preparation. There will be at least one man in the I.C. group every month or oftener that receives a slight shock. This can be the basis of the discussion. Have the man concerned relate the exact circumstances under which he received the shock. The group then discusses the slightly different conditions that might have prevailed causing the shock to be more severe or perhaps fatal.

The film list in appendix I of this training course includes film concerning safety that will be helpful both as safety reminders and for safety education.

ENFORCING SAFETY

Safety precautions as all rules, laws, or regulations must be enforced. It is your duty to take appropriate action any time you see a junior man disregarding a safety precaution. You must require that all jobs relating to the I.C. equipment be done according to applicable safety precautions.

Doing a job the safe way in some cases may take a little longer or be a little more inconvenient, however, there is no doubt as to the importance of doing it this way fig. 9-1).

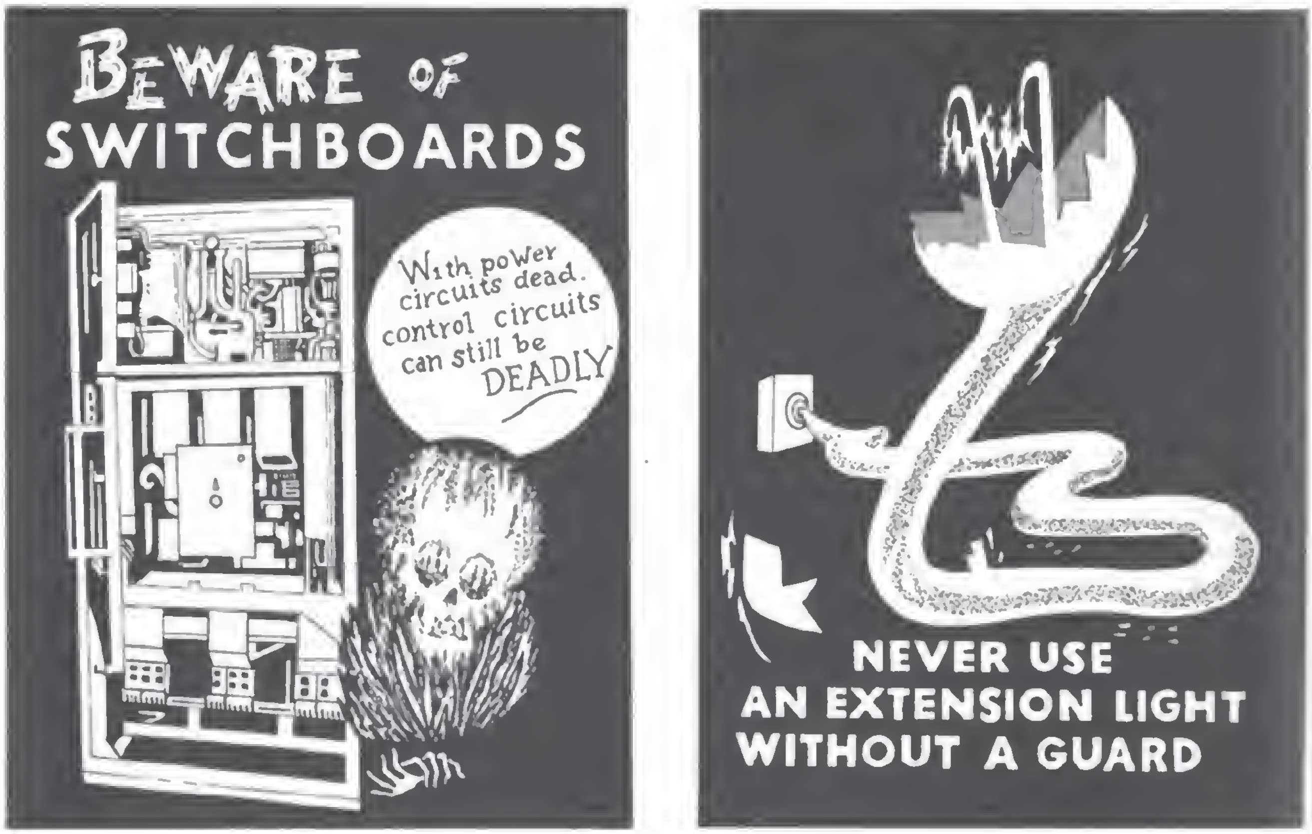

Figure 9-2.—Sample—electrical safety posters.

APPENDIX I
TRAINING FILM LIST

Training films that are directly related to the information presented in this training course are listed below. Under each chapter number and title the training films are identified by Navy number and title and are briefly described. Other training films that may be of interest are listed in the United States Navy Film Catalog, NavPers 10000 (revised).

Chapter 1

ADVANCEMENT

No applicable training list.

Chapter 2

ORGANIZATION AND ADMINISTRATION

No applicable training list.

Chapter 3

RECORDS AND REPORTS

No applicable training list.

Chapter 4

MAGNETIC AMPLIFIER APPLICATIONS

MN 8483B Magnetic Amplifiers—Circuits and Applications. (17 min.—B&W—Unclassified—1957.) Describes advantages of magnetic amplifiers and gives examples of their use. Describes the effects of adding rectifiers, "crossover" windings, resistors, and feedback windings.

Chapter 5

GYROCOMPASSES (Part I)

No applicable training list.

Chapter 6

GYROCOMPASSES (PART II)

MN-7465A Gyrocompasses Mark 19 Mod 3 and Mark 23—Earth Rates. (17 min.—B&W—Sound—Unclassified—1954.) Shows how gravity works with the principles of rigidity, precession and earth rate to make a gyrocompass out of the gyroscope.

MN-7465B Gyrocompasses Mark 19, Mod 3 and Mark 23—The Gyro as a Compass. (15 min.—B&W—Sound—Unclassified—1954.) Shows how the rotation of the earth causes apparent rotation of the gyroscope about its horizontal axis, about its vertical axis and about both the horizontal and vertical axis.

MN-7465C Gyrocompasses Mark 19, Mod 3 and Mark 23—General Description. (25 min.—B&W—Sound—Unclassified—1954.) Describes the five major components of the complete Mark 23 equipment. The functions of certain parts are explained.

MN-7465D Gyrocompasses Mark 19, Mod 3 and Mark 23—Compass Control Mark 23. (15 min—B&W—Sound—Unclassified—1954.) Describes the three sections of the compass control system. Gives details of function, design and operation of all components. Shows how the tilt indicator is connected to the system and how it operates.

MN-7465E Gyrocompasses Mark 19, Mod 3 and Mark 23—Errors and Corrections Mark 23. (18 min.—B&W—Sound—Unclassified 1954.) Names the three correction signals included in the compass control system for vertical earth rate, balance compensation and northerly speed. Describes the need for and the method of compensating for variations in line voltage.

MN7465F Gyrocompasses Mark 19, Mod 3 and Mark 23—Followup System Mark 23. (13 min.—B&W—Sound—Unclassified—1954.) Describes the need for followup and shows by technical animation the three parts of the followup system, the pick-off, and operation of all components. Shows how the heading transmitters, the manual azimuth switches and the followup failure alarm tie in with the system.

MN-7465G Gyrocompasses Mark 19, Mod 3 and Mark 23—Operation and Maintenance Mark 23. (20 min.—B&W—Sound—Unclassified —1954.) Describes normal and directional gyro modes of operation by means of live action photography. Shows complete procedure for starting and securing the compass and for making routine checks. Outlines both preventive and corrective maintenance, including trouble-shooting typical cases of malfunctioning.

Chapter 7

DEAD-RECKONING SYSTEM

No applicable training list.

Chapter 8

CLOSED CIRCUIT TELEVISION

No applicable training list.

Chapter 9

SAFETY PRECAUTIONS

MN-9333 Electrical Maintenance. (15 min.—B&W—Sound—Unclassified —1952.) USAF TFL-4699. Emphasizes safety in electrical maintenance. Shows some of the tragic results caused by carelessness. Electrical systems must be checked and double checked before wiring or replacing condensers, fuses, etc. Carelessness in electrical maintenance in buildings or planes causes fires, serious accidents, and death. The fuse is the safety valve of the electrical system—don't use oversize fuses! Importance of grounding planes and trucks before refueling is emphasized.

SN-6 Sharpening Drills—Grinding Tools. (12 min.—27 frames—B&W —Sound—Unclassified—1941.) Presents correct method of grinding and sharpening chisels, use and care of goggles, punches, scribers, screwdrivers, and drills. Stresses precautions to be observed.

MC-4597 For Safety's Sake. (13 min.—B&W—Sound—Unclassified—1945.) Explains necessary precautions in handling portable power tools with emphasis on drills, grinders, and electric saws. Stresses importance of wearing goggles, keeping equipment in good condition, and grounding equipment. Uses actual accidents to demonstrate results of carelessness.

MN-1921F To Live In Darkness. (14 min.—B&W—Sound—Unclassified—1944.) Shows that many cases of loss of sight could have been prevented by wearing the right goggles at the right time in the right place. Shows cases of three men whose loss of sight was avoidable.

MN-6754 Safety Precautions for Electronics Personnel—Introduction. (15 min.—B&W—Sound—Unclassified—1951.) Shows electrical and mechanical hazards which Electronics Technicians encounter in normal work and stresses precautions which should be employed to prevent accidents. Film content includes procedures for working on energized and de-energized circuits, handling of cathode-ray tubes, preventive measure aboard ship, and hazards of carelessness and practical jokes. Stresses necessity for cultivation of safe working habits.

MN-6939 Accident Prevention Aboard Ship. (9 min.—Color—Sound—Unclassified—1952.) Directed toward building safe-minded attitudes for naval personnel through caricature of a number of typical shipboard accidents.

MN-8990 115 Volts-Deadly Shipmate. (19 min.—Color—Sound—Unclassified—1960.) This film tells the story of Joe who is representative of all sailors, and is based upon the reenactment of actual cases. It emphasizes the disastrous effects of low voltage electrical shock when the basic rules of electrical safety are violated or ignored.

SC-8358 This Will Kill You. (20 min.—Color—Sound—Unclassified.) Shows many examples of casualties and fatalities; explains current, heat burns, first aid, differences between effects of a-c and d-c damage, and has a summary based upon a variety of case histories. All of the major "do's" and "don'ts" of electrical accidents are forcefully presented.

MN-8639 Safety On-the-Job at Sea. (16 min.—B&W—Sound—Unclassified—1957.) This film shows organization for shipboard safety, how shipboard accidents can occur, accident prevention afloat, and emphasizes the importance of crew safety consciousness.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

INTERIOR COMMUNICATIONS ELECTRICIAN (IC)

Quals Current Through Change 19

GENERAL RATING

Scope

Interior Communications Electricians: Maintain and repair interior communications (IC) systems, gyrocompass systems, amplified and unamplified voice systems, and related equipment; and stand IC and gyrocompass watches.

SERVICE RATINGS

None.

PATH OF ADVANCEMENT TO LIMITED DUTY OFFICER

Interior Communications Electricians advance to Limited Duty Officers, Electrician.

NAVY ENLISTED CLASSIFICATION CODES

See Manual of Navy Enlisted Classifications, NavPers 15105-B.

QUALIFICATIONS FOR ADVANCEMENT IN RATING

1. Qualifications for advancement to a higher rate include the qualifications of the lower rate or rates in addition to those stated for the higher rate.
2. Practical factors will be completed before recommendation for participation in the advancement examination. (Bureau of Naval Personnel Manual, NavPers 15791-A, Articles B-2326 and C-7201.)
3. Knowledge factors and knowledge aspects of practical factors will form the basis for questions in the written advancement examination.

Qualifications for advancement in rating	Applicable Rates IC
A. THEORY OF ELECTRICITY/ELECTRONICS	
1.0 Practical Factors	
None.	
2.0 Knowledge Factors	
1. Meaning of:	
a. Conductor and insulator	3
b. Magnetic lines of force	3
c. Field intensity	3
d. Flux density	3
e. Permeability	3
f. Ampere-turn	3
g. Hysteresis and eddy current	3
h. Self- and mutual-induction	3
i. Electromagnetic induction.	3
j. Coulomb	3
k. Volt	3
l. Ampere	3
m. Ohm	3
n. Henry	3
o. Circular mill	3
p. Farad	3
q. Watt	3
r. Horsepower	3
s. Power factor	3
t. Volt-ampere.	3
u. Reactance	3
v. Capacitance	3
w. Inductance	3
x. Impedance	3
y. Torque	3
z. Frequency	3
aa. Cycle	3
bb. Phase	3
cc. Noise	3
dd. Pulse	3
ee. Ambient temperature	3
ff. Amplifier.	3
gg. Micro, kilo, and mega as applied to any of the above units of measure	3
hh. Gain	3
ii. Feedback.	2
jj. Bias	2
kk. Cutoff	2
ll. Plate current	2
mm. Grid current.	2
nn. Electron tube characteristics	2

Qualifications for advancement in rating	Applicable Rates IC
A. THEORY OF ELECTRICITY/ELECTRONICS—Continued	
2.0 Knowledge Factors—Continued	
oo. Phase distortion	2
pp. Amplitude	2
qq. Transistor characteristics	2
2. Relation of current, voltage, and impedance in a.c. circuits	3
3. Relation of reluctance, flux, and magnetomotive force in a.c. and d.c. circuits	3
4. Relation of resistance, temperature, and current in an electrical conductor	3
5. Relation of length and cross-sectional area to resistance of a conductor	3
6. Function, operating principles, and construction of:	
a. Electron tubes	3
b. Electron, gas-filled, and cathode ray tubes	3
c. Transistors and diodes	3
7. Characteristics and use of synchros; purpose and methods of setting to electrical zero	3
8. Methods of coupling amplifier stages; transformer impedance, capacitive, resistive, and direct	3
9. Characteristics and use of synchroamplifiers; purpose of gain, feed, and balance adjustments	2
10. Application of laws of magnetism to electric rotating machinery	2
B. EQUIPMENT, DEVICES, AND SYSTEMS	
1.0 Practical Factors	
1. Energize, start, test, operate, and secure ship's metering and indicating, control, alarm and warning, and signal systems; gyrocompass and associated equipment; and amplified voice and projection equipment	3
2. Interpret MILSTDS color coding of capacitors, resistors, internal connections of power and audio transformers, and chassis wiring	3
3. Cross-connect IC systems to operate under battle, emergency, and casualty conditions	2
4. Effect authorized field changes to IC equipment	1
2.0 Knowledge Factors	
1. Construction and operating principles of power units, such as control panels, transformers, and rectifiers	3
2. Construction and operating principles of basic mechanisms, such as shafts, gears, cams, ratchets, springs, and friction disks with roller assemblies	3

Qualifications for advancement in rating	Applicable Rates IC
B. EQUIPMENT, DEVICES, AND SYSTEMS—Continued	
2.0 Knowledge Factors—Continued	
3. Construction and operation of:	
a. Underwater log	3
b. Wind indicators	3
c. Ship-control order and indicating systems	3
d. Amplifier announcing systems	2
e. Gyrocompass	2
f. Magnesyn compass systems	2
g. Magnetic amplifiers	2
h. Automatic telephones	2
i. Closed-circuit television	1
C. MAINTENANCE	
1.0 Practical Factors	
1. Make tests for, locate, and clear short and open circuits and grounds in cables, wiring, fittings, buzzers, call bells, and other simple circuits	3
2. Inspect, clean, and lubricate IC equipment in accordance with technical-maintenance publications	3
3. Calculate current, voltage, and resistance in d.c. series and parallel circuits of not more than four elements	3
4. Use and perform preventive maintenance on the following test equipment:	
a. Nonelectronic volt-ohm-ammeter	3
b. Electronic volt-ohm-ammeter	3
c. Tube tester	3
d. Megger	3
e. Tachometer	3
f. Circuit analyzer	2
g. Oscilloscope	2
h. Signal generator	2
5. Test, repair, and/or replace parts, such as relays, plugs, lamps, fuses, switches, tubes, jacks, cable, wiring, fixed capacitors, variacs, transformers, fixed resistors, and potentiometers within a component, assembly, or subassembly	2
6. Localize casualties and perform corrective maintenance on the following:	
a. Alarm and warning systems, including toxic vapor and contaminated air systems	3
b. Ship order and indicating units (synchro)	3
c. Underwater logs	3
d. Wind indicators	3
e. Cables, wiring, and fittings	3

Qualifications for advancement in rating	Applicable Rates IC
C. MAINTENANCE—Continued	
1.0 Practical Factors—Continued	
f. Sound-powered handsets and headsets	3
g. Ship control order and indicating systems	3
h. Voice recorders and record players	2
i. Sound motion picture projectors (16 mm)	2
j. Intercoms and portable announcing systems	2
k. Motor-generator sets and control panels as applied to IC equipment	2
l. Central amplifier systems	2
m. Magnetic amplifiers	2
n. Sound-powered telephone circuits	2
o. Magnesyn compass	2
p. Constant frequency control	2
q. Automatic telephones	2
r. Gyrocompass and associated equipment, such as dead-reckoning analyzer (DRA), dead-reckoning tracer (DRT), and gyrorepeaters	1
s. Self-synchronous alidades	1
t. Synchroamplifier	1
7. Make tests, adjustments, and repairs necessary for proper operation of synchrocontrol circuits including servoloops	1
8. Test, remove, and install meters and instrument transformers	1
9. Make periodic inspections and internal adjustments of IC units	1
10. Tighten connections on switchboards and control panels	1
11. Test and evaluate new or overhauled components, assemblies, or subassemblies of IC equipment for proper and secure installation and optimum performance	C
12. Analyze and evaluate electrical and electronic tests; make adjustments, calibrations, and repairs for optimum performance of IC equipment	C
2.0 Knowledge Factors	
1. Lubricants, cleaning materials, and solutions used in the maintenance of IC equipment	3
2. Procedures for replacing:	
a. Electron tubes	3
b. Transistors and solid state diodes	2
D. MOTORS, GENERATORS, AND RELATED EQUIPMENT	
1.0 Practical Factors	
1. Inspect and clean commutators and slipring assemblies	3

Qualifications for advancement in rating	Applicable Rates IC
D. MOTORS, GENERATORS, AND RELATED EQUIPMENT—Continued	
1.0 Practical Factors—Continued	
2. Replace and adjust brushes on commutators and slip-ring assemblies	2
3. Adjust voltage regulators	1
2.0 Knowledge Factors	
1. Construction of motors, generators, and alternators	2
E. CABLES, CIRCUITS, AND SWITCHBOARDS	
1.0 Practical Factors	
1. Renew section of cable between:	
a. Junction boxes	3
b. Junction boxes and equipment	3
2. Make electrical connections and splices including soldered joints and pressure-type terminals (solderless type)	3
3. Identify by marking systems, electric cables, wiring, and fittings	3
4. Operate IC switchboards:	
a. Transfer circuits for normal, battle, emergency, and casualty conditions	3
b. Set up control circuits for anchor and underway conditions	3
5. Test IC circuits that are external to major units of IC equipment for continuity, short circuits, and grounds; measure electrical quantities such as voltage, current, and power, and compare with established values	3
6. Test internal circuits of major units of IC equipment for continuity, short circuits, and grounds; measure electrical quantities such as voltage, current, and power, and compare with established values; use an oscilloscope to view circuit waveforms and compare with established optimum-performance waveforms required in IC equipment	2
7. Replace necessary leads for connecting a synchrogenerator to independent synchromotors through a rotary switch	2
8. Connect casualty powerlines	1
2.0 Knowledge Factors	
1. Construction, types, and uses of shipboard electric cable	3

Qualifications for advancement in rating	Applicable Rates
	IC
E. CABLES, CIRCUITS, AND SWITCHBOARDS—Continued	
2.0 Knowledge Factors—Continued	
2. Normal, alternate, and emergency-power distribution sources for shipboard lighting and IC power	3
3. Function of circuit components, such as:	
a. Resistors.	3
b. Rheostats.	3
c. Potentiometers	3
d. Solenoids	3
e. Inductors	3
f. Capacitors	3
g. Fuses	3
h. Switches	3
i. Transformers.	3
j. Relays.	3
k. Saturable reactors.	2
4. Methods of obtaining three general types of bias: fixed, cathode, and grid leak.	2
5. Principles of IC polyphase circuits	2
6. Methods and procedures for overhaul of IC switchboards	1
F. MATERIALS AND EQUIPMENT	
1.0 Practical Factors	
1. Select, use, and maintain electrician's common hand and small bench tools including soldering equipment and electric-powered tools such as drills and grinders provided for maintenance and repair of IC equipment	3
2. Inspect, maintain, test, and install storage and dry cell batteries	3
3. Inspect extension cords and portable power and bench tools for proper connections and continuity of grounding circuits.	2
2.0 Knowledge Factors	
1. Care and storage of IC materials	3
2. Types and identification of insulating materials and varnishes	3
3. Types, structure, and electrical characteristics of batteries	3

Qualifications for advancement in rating	Applicable Rates IC
G. PUBLICATIONS AND DIAGRAMS	
1.0 Practical Factors	
1. Interpret electric, electronic, and mechanical symbols shown in schematic and wiring diagrams, IC technical-maintenance publications, and installation blueprints	3
2. Use technical and supply publications for identifying and selecting materials and parts	3
3. Prepare diagrams and sketches of IC devices and equipment, using standard designations for cables, wiring, terminal markings, and circuit components	C
2.0 Knowledge Factors	
None.	
H. ADMINISTRATION, SUPERVISION, AND TRAINING	
1.0 Practical Factors	
1. Prepare requisitions for tools and replacement parts	3
2. Maintain all required records at watch station	3
3. Supervise setting up of public address systems	2
4. Take charge of gyrocompass and IC watches	2
5. Take, record, and report inventories of tools and portable test equipment available for maintenance and repair of IC equipment	2
6. Supervise the underway watch in the IC room	1
7. Prepare job orders and work requests for both tender and shipboard repairs of IC or gyrocompass equipment	1
8. Plan, organize, and direct work of personnel operating, maintaining, and repairing IC and gyrocompass systems	C
9. Estimate time, materials, and labor required for repair of IC systems and equipment	C
10. Supervise and train personnel in operation, maintenance, and repair of IC and gyrocompass equipment	C
2.0 Knowledge Factors	
1. Systems of assigning "AN" letter combinations as designation for IC equipment	3
2. Types of entries and information recorded in IC equipment failure reports, work logs, equipment histories, checkoff lists, and current ship's maintenance project (CSMP)	3

Qualifications for advancement in rating	Applicable Rates IC
3. Types of information reported in periodic or recurcurring reports concerning performance and maintenance of IC equipment.	1
4. Accounting procedures for equipment, maintaining control of inventories and workflow, and reporting equipment status and work accomplished	C
I. SAFETY, FIRST AID, AND FIREFIGHTING	
1.0 Practical Factors	
1. Rescue a person in contact with an energized circuit, resuscitate a person unconscious from electric shock; treat for electric shock and electric and acid burns . .	3
2. Demonstrate and observe while servicing equipment, safety precautions such as tagging switches, removing fuses, grounding test equipment using shorting bar and rubber mats	3
3. Extinguish electrical fires, using CO_2 extinguishers (simulated conditions).	3
2.0 Knowledge Factors	
1. Electrical and electronic safety precautions, including those set forth in Chapter 18, U.S. Navy Safety Precautions (OPNAV 34P1), to be observed in servicing IC equipment.	3
2. Effects of electrical shock.	3
3. Precautions to be observed in the use of cleansers and lubricants.	3

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